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Royal Botanic Gardens Melbourne

***Allocasuarina luehmanni* (R.T. Baker) L.A.S. Johnson** [JH. Maiden *For.Fl.NSW*, v.II, Pl 76 (1907)]
Source: State Botanical Collection
Artist: M. Flockton
The common name for this plant is 'Bull Oak' or 'Buloke'. *Allo-* Greek for 'other'; *Cosuarino*, owing to the resemblance of the branchlets to the feathers of the *Cassowory* (*Cosuarius*); and *luehmonni*, in honour of Johann Georg Luehmann, successor to Mueller as Government Botanist of Victoria.

Muelleria publishes research papers on Southern Hemisphere plant, algal and fungal taxonomy and systematics, particularly relating to Australia. Acceptable submissions include: taxonomic revisions; phylogenetic and biogeographical studies; short papers describing new taxa, documenting nationally significant new records, or resolving nomenclatural matters; historical analyses relevant to systematics; and any research contributing to our knowledge of plant, algal or fungal diversity. Special issues or reviews will also be considered after discussion with the Editor.

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Manuscripts & proofs	Royal Botanic Gardens Melbourne Private Bag 2000 Birdwood Avenue South Yarra VIC 3141 Australia muelleria@rbg.vic.gov.au
Publication times	January and July
Instructions	Please consult the Instructions to Contributors at the website below. A concise version is printed inside the back cover of each issue. www.rbg.vic.gov.au/science/information-and-resources/science-publications/muelliera
Subscriptions	The Editor, *Muelleria*
Exchange	For all enquiries about exchange or missing issues please contact the Library Manager at the above address or at: library@rbg.vic.gov.au

Subscription rates		Within Australia	Overseas
(annually – 2 issues)	Individuals	$80	$90
Includes airmail & GST	Organisations	$100	$120

Cheques to be made payable to the Royal Botanic Gardens Melbourne. All payments must be in $AUD.

Layout: SUBStitution Pty Ltd

Printer: BigPrint

Recycled Paper

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ISSN 0077-1813

Muelleria **volume 29(1) was distributed on 10 January 2011**

Muelleria

Contents

Volume 29(2) 2011

Royal Botanic Gardens
Melbourne
- 1 JUL 2011
LIBRARY

Royal Botanic Gardens Melbourne

Contributed Papers

Page

The lichen genera *Japewia* and *Japewiella* in Tasmania 99
– G. Kantvilas

Sex discrimination of Buloke (*Allocasuarina luehmannii*) for selective revegetation 104
– M. Conomikes, M. Wright and J. Delpratt

Resolution of the *Thelymitra aristata* (Orchidaceae) complex of south-eastern Australia 110
–J. Jeanes

The functional significance for the orchid *Caladenia tentaculata* of genetic and geographic variation in the mycorrhizal fungus *Sebacina vermifera* s. lat. complex 130
– M. Wright, R. Cross, R.D. Cousens, T.W. May and C.B. McLean

A revision of *Goodia* (Fabaceae: Bossiaeeae) 141
– I.R. Thompson

A revision of *Platylobium* (Fabaceae: Bossiaeeae) 154
– I.R. Thompson

A revision of *Muelleranthus*, *Ptychosema* and *Aenictophyton* (Fabaceae: Bossiaeeae) 173
– I.R. Thompson

A morphological comparison between *Digitaria coenicola* and *D. divaricatissima* (Poaceae: Paniceae) 190
– H. Stewart and N. Walsh

Corrigendum

Muelleria 29(1): (2011) 201

The lichen genera *Japewia* and *Japewiella* in Australia

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Introduction

The genus *Japewia* was introduced by Tønsberg (1990) to accommodate three corticolous crustose taxa from the cool temperate Northern Hemisphere, characterised principally by their biatorine apothecia and unusually thick-walled, simple ascospores. Other salient features included eight-spored asci with a conspicuous masse axiale (± pertaining to the *Lecidella*-type of Hafellner 1984), the hamathecium and excipulum both comprised of highly similar, branched and anastomosing, gelatinised hyphae, and capitate, brown-pigmented paraphysis tips (Printzen 1999). As pointed out by Printzen (1999), *Japewia* as thus defined, and with only three constituent species, was already heterogeneous, because one species, *J. carrollii* (Coppins & P.James) Tønsberg, had a well-developed excipulum unlike that of *J. tornoensis* (Nyl.) Tønsberg (the type species) and *J. subaurifera* Muhr & Tønsberg. Consequently (*loc. cit.*), he introduced the genus *Japewiella* to accommodate not only *J. carrollii* but also two additional species from more temperate to subtropical latitudes.

Neither genus has been recorded for Australasia, but as is so often the case, this is more a result of lack of knowledge and collections, than a true reflection of biogeographical patterns. Ongoing study of crustose lichens in Tasmania has revealed that both genera are indeed present there. These findings are reported below.

Material and Methods

The study is based on specimens housed in the Tasmanian Herbarium (HO), and comparative reference material in the Natural History Museum (BM).

Descriptions are based on hand-cut sections of the thallus and ascomata, mounted in water, 15% KOH, Lugols Iodine and Lactophenol Cotton Blue, and examined with high-power, light microscopy. Dimensions of asci and ascospores are based on 25 and 50 observations respectively. The latter are presented in the format: smallest measurement–*mean*–largest measurement; single outlying values are given in parentheses. Chemical analyses using thin-layer chromatography follow standard methods (Orange *et al.* 2001) and comparison with a range of reliable reference specimens. High-performance liquid chromatography (Elix

Abstract

The genera *Japewia* and *Japewiella* (lichenised Ascomycetes) are recorded for Australia for the first time, based on collections from Tasmania. The species *Japewia subaurifera* Muhr & Tonsberg and *Japewiella pruinosula* (Müll.Arg.) Kantvilas *comb. nov.* are described and discussed. The latter is also known from New South Wales and Victoria.

Keywords: lichenised Ascomycota, Tasmania.

Muelleria 29(2): 99-103 (2011)

et al. 2003) of selected specimens was undertaken by Prof. J.A. Elix in Canberra. Nomenclature of ascus types follows Hafellner (1984).

Taxonomy

Japewia subaurifera Muhr & Tønsberg

Lichenologist 22: 206 (1990); ***Type:*** Norway: Nord-Trondelag, Namsskogan, N of river Namsen, along Åsbekken 5 of hill Smalåsenden, 200–300 m alt., 8 April 1982, *T. Tønsberg 6590* (isotype – BM!).

Thallus crustose, areolate, dull chestnut brown, sorediate; areoles 0.15–0.3 mm wide, ecorticate, rather gnarled, dispersed or crowded and fusing together to form an irregular, rather granular, irregularly spreading crust to c. 3 mm wide and 1 mm thick; soredia erumpent, rather coarse, pale yellowish green at first, discoloring brownish with age. *Photobiont* a unicellular green alga with ± globose cells 6–15 µm wide. *Apothecia* very infrequent, 0.3–0.6 mm wide, biatorine, sessile, immarginate; disc plane to strongly convex, chestnut brown, glossy, epruinose. *Proper excipulum* very thin and reduced, becoming indistinct and excluded with age, in section ± annular, poorly differentiated from the hymenium, hyaline within, reddish brown, K+ dirty brown at the outer edge due to the pigmentation of the outermost cells, composed of entangled, branched and anastomosing, gelatinised hyphae 1.5–2 µm thick, similar to the paraphyses. *Hypothecium* to c. 75 µm thick, hyaline to dilutely yellowish brown. *Hymenium* 60–75 µm thick, not inspersed, KI+ blue but with the amyloid reaction confined to the asci, hyaline to dilutely yellowish to reddish brown, overlain by a reddish brown, K+ dirty brown epithecial layer composed of the pigmented apices of the paraphyses. *Asci* broadly ellipsoid, 45–55 × 18–30 µm, (1–)2–6(–8)-spored, approximating the *Lecidella*-type: tholus well-developed, intensely amyloid, almost but not entirely pierced by a conical to barrel-shaped, weakly amyloid masse axiale with a rounded apex; ocular chamber poorly developed. *Paraphyses* 1–1.5 µm thick, branched and anastomosing, gelatinised, ± identical to the excipular hyphae; apices 3–5 µm wide, pigmented, typically also with a gelatinous sheath. *Ascospores* simple, hyaline, broadly ellipsoid to ovate, non-halonate, (13–)15–*19.0*–22(–23) x (10–)12–*13.9*–17(–18) µm; wall 2–4 µm thick, clearly two-layered. *Conidia* not seen.

Chemical composition: no substances detected in Tasmanian material but lobaric acid has been reported occasionally in the Northern Hemisphere (Tønsberg 1990); secalonic acid has also been reported (Elix & Tonsberg 1999).

Specimen examined: **Australia: Tasmania:** summit of Wild Dog Tier, 41°47'S 146°35'E, 1390 m altitude, 2001, *G. Kantvilas 376/01* (HO).

Remarks: *Japewia subaurifera* is a small but nevertheless distinctive species, due to the brown granular thallus, pale yellowish soredia, glossy brown apothecia and thick-walled ascospores. It is widespread in cool to cold, boreal and oceanic regions of the Northern Hemisphere where it occurs on bark in woodland. The single Tasmanian collection is from a dead, decorticated, bleached twig, lying on the ground in a small (a few square metres), isolated pocket of unburnt alpine heathland. This highly localised site supports several additional lichen species which, in Tasmania, are either relatively uncommon (*Cetraria australiensis* W.A.Weber ex Kärnefelt) or extremely rare (*Umbilicaria decussata* (Vill.) Zahlbr., *Xylographa* sp.). The tiny collection of *Japewia* comprises a single fragmented thallus with just three fruiting bodies, hidden in a fissure in the twig. Persistent, targetted searches for the species at many similar locations on Tasmania's Central Plateau have been fruitless.

The Tasmanian specimen has ascospores that are somewhat larger (broader) than those reported in the original description [11–20 x (8–)12–13(–14) µm: Tønsberg (1990)]. However, the paucity of material available precludes inferring any taxonomic significance in this observation.

The taxonomic affinities of *Japewia* remain unclear, and at present, the species is included by Lumbsch & Huhndorf (2007) in the Ramalinaceae. On the basis of ascus structure and ascospore morphology, this position is certainly incorrect (Ekman 1996; Hertel & Rambold 1995). In the revision of Southern Hemisphere *Mycoblastus* based on anatomical, morphological and chemical data, Kantvilas (2009) noted that *Mycoblastus dissimulans* (Nyl.) Zahlbr. and its allies, which comprise the majority of Southern Hemisphere species, displayed noteworthy similarities to *Japewia*. In the present study, after an extensive examination of *Japewia*, this perception has been reinforced. The similarities in the

general appearance of the photobiont, and the anatomy of the asci, excipulum, paraphyses and ascospores are startling. The main difference is that species of the *Mycoblastus dissimulans* group have black (or at least dark) apothecia containing greenish or violet pigments that react in KOH and HNO_3, typically contain perlatolic acid and have incrementally larger ascospores.

Japewiella pruinosula (Müll. Arg.) Kantvilas comb. nov.

Lecidea pruinosula Müll.Arg., *Flora* 65: 486 (1882); *Lecidella pruinosula* (Müll. Arg.) Kantvilas & Elix, *Pap. & Proc. Roy. Soc. Tasmania* 142: 53 (2008).

Type: Australia, New South Wales, corticola ad Twofold Bay, *T. White* (holotype: G!).

Biatora cerarufa Shirley, *Pap. & Proc. Roy. Soc. Tasmania* 1893: 217 (1894); *Lecidea cerarufa* (Shirley) Zahlbr., *Cat. Lich. Univ.* 3: 746 (1925).

Type: Australia, Tasmania, on bark, Bower Track, Mt Wellington, *W.A. Weymouth 141* (holotype: BRI!).

Thallus crustose, effuse, creamish white, smooth, cracked or somewhat scurfy, ecorticate, continuous or rather patchy, 30–100(–200) µm thick, forming irregular, undelimited patches to c. 4 cm wide. *Photobiont* a unicellular green alga with ± globose cells 5–12 µm wide. *Apothecia* biatorine, sessile, basally constricted, 0.3–1 mm wide; disc pale pink, orange or reddish brown, occasionally dark brown, often whitish grey pruinose, at least when young, typically persistently plane. *Proper excipulum* well developed, persistent, mostly elevated above the level of the disc, with the rim pale orange-brown to brown and the sides much paler, sometimes appearing almost lecanorine, in section cupular (or almost so), 30–100 µm thick, hyaline within, diffusely pale red-brown, K± dirty brown near the outer edge, usually densely inspersed with crystals that fluoresce in polarised light but do not dissolve in KOH, composed of radiating, branched and anastomosing hyphae *c.* 1 µm thick in a gelatinous matrix. *Hypothecium* (30–)40–110 µm thick, hyaline to pale yellowish. *Hymenium* 70–110 µm thick, hyaline, KI+ blue, overlain by a diffusely reddish brown, K+ dirty brown epithecial layer 5–10 µm thick, composed chiefly of granules that do not dissolve in KOH. *Asci* clavate, 55–70 × 14–24 µm, eight-spored but frequently with up to 4 spores aborted, approximating the *Lecidella*-type: tholus well-developed, intensely amyloid, with a ± barrel-shaped, rather fuzzy, weakly amyloid masse axiale with a rounded apex; ocular chamber poorly developed. *Paraphyses* simple to sparingly branched, 1–2 µm thick, sometimes with swollen, oily vacuoles to 5 µm wide ('oil paraphyses'); apices unpigmented and only occasionally swollen to 2.5 µm. *Ascospores* simple, hyaline, broadly ellipsoid, ovate to subglobose, often squashed and deformed when in the ascus, (10–)12–*15.4*–20(–21) × 8–*10.6*–14 µm; wall single-layered, to 0.8 µm thick. *Conidiomata* unknown. Fig 1 A-B.

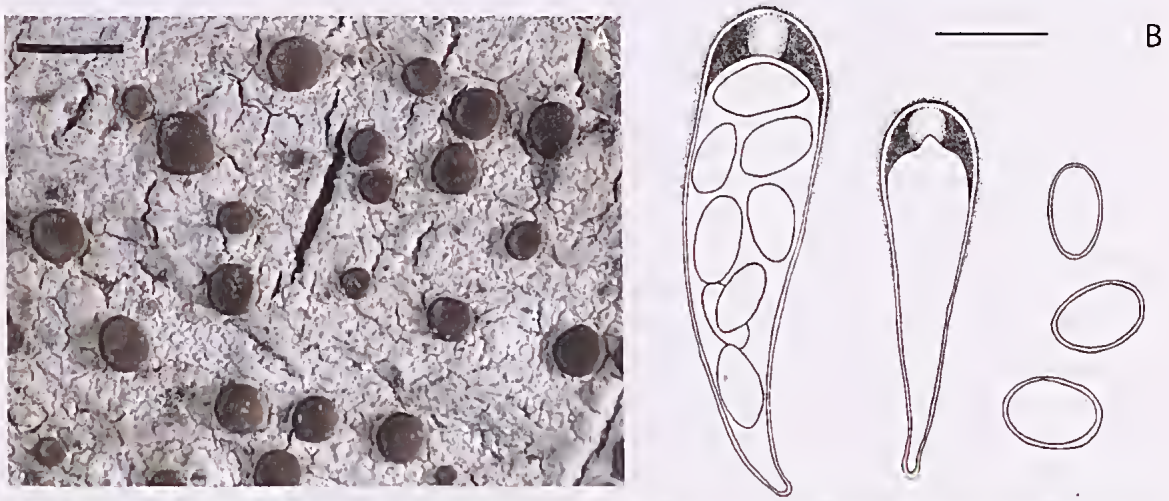

Figure 1. A. *Japewiella pruinosula* habit (*Bratt et al. 76/444*). Scale = 1 mm; B. *Japewiella pruinasula* anatomy: asci with amyloid parts stippled and ascospores (*Kantvilas 114/86*). Scale = 20 µm.

Chemical composition: pannarin (± minor), dechloropannarin (± minor), norpannarin (± trace), 3-*O*-methylthiophaninic acid (±), 2,5,7-trichloro-3-*O*-methylnorlichexanthone, 5,7-dichloro-3-*O*-methylnorlichexanthone (± minor), thiophaninic acid (± minor), isoarthothelin (± minor), 3-*O*-methylthiophaninic acid (± trace). These substances are rarely in sufficient concentrations to offer reliable spot or UV tests, although the grey pruina of young apothecia may give a P+ orange reaction. The complex and variable chemistry of this taxon was determined using h.p.l.c. by J.A. Elix in Kantvilas *et al.* (2008). With simple t.l.c, few of the substances can be detected, with the exception of two fast-moving xanthones (3-*O*-methylthiophaninic acid (±), 2,5,7-trichloro-3-*O*-methylnorlichexanthone) that appear as pale UV+ spots on developed t.l.c. plates.

Selected specimens examined: **Australia: Tasmania:** Huon Road, Watchorns Hill, 42°57'S 147°14'E, 480 m alt., 1899, *W.A. Weymouth 674* (HO); Dee Lagoon, 42°16'S 146° 36'E, 690 m alt., 1964, *G.C. Bratt & J.A. Cashin 1800b* (HO); near Lynchford Siding, 42°07'S 145°32'E, 1976, *G.C. Bratt 76/44 et al.* (HO); Queenstown, 42°05'S 145° 33'E, 200 m alt., 1984, *G. Kantvilas 189/84 & P.W. James* (BM, HO); Rapid River Road, 41°07'S 145°07'E, 170 m alt., 1986, *G. Kantvilas 114/86* (BM, HO); Sandspit River, 42°42'S 147°50'E, 180 m alt., 1988, *A. Moscal 16846* (HO). **Victoria:** Brighton, Jim Willis Reserve, 37°55'23" 144°59'14", *V. Stajsic 4061 p.p.* (HO); Drummer Rainforest Walk, 10 km E of Cann River township, 37°34'08"S 149°16'21"E, 145 m alt., 2010, *G. Kantvilas 249/10* (HO); Errinundra NP, Tea Tree Flat, 37°14'33"S 148°50'06"E, 880 m alt., 2010, *G. Kantvilas 264/10* (HO, MEL).

Remarks: *Japewiella pruinosula* is a distinctive species, both macroscopically because of the persistently marginate, often pruinose apothecia, and microscopically due to the internally unpigmented apothecia with *Lecidella*-type asci and large, broad ascospores. Perhaps the most similar species in the Tasmanian flora is the corticolous *Lecidea immarginata* R.Br., which also has reddish brown apothecia and large simple ascospores. However, this species never has a pruinose apothecial disc, the apothecia frequently become immarginate, the asci approximate the *Porpidia*-type (showing a well developed, deeply amyloid, divergent ring structure in the tholus) and the thallus lacks any substances detectable by t.l.c. Also sometimes similar are some forms of the coastal epiphyte *Lecanora flavopallida* Stirt., which has similar-looking apothecia but differs by having a thallus with a yellowish tinge, containing thiophaninic acid, and distinctly *Lecanora*-type asci.

Japewiella pruinosula is common and widespread in Tasmania in wet eucalypt forest, wet scrub and rainforest, where it occurs on trunks and twigs with smooth bark, typically in well-lit conditions but also sometimes beneath a sparse forest canopy. Tiny thalli are commonly found on dead canopy twigs of eucalypts. It is also known from the south-eastern Australian mainland (Victoria and New South Wales).

The taxonomic placement of this species has taken several iterations. Interestingly, its affinities were first correctly interpreted almost 25 years ago by the British lichenologist Peter James (*in litt.*), who examined a specimen and suggested it was 'reminiscent of *Lecidea carrolli* Coppins & P. James'; that taxon is now known as *Japewiella tavaresiana* (H. Magn.) Printzen. In the meantime, it remained classified in *Lecidea* (Kantvilas 1988) before being transferred to *Lecidella* in Kantvilas *et al.* (2008) on account of the thallus containing xanthones and the *Lecidella*-type asci. However, *Lecidella* differs by having an excipulum composed of parallel, radiating, relatively thick hyphae with dark greenish or bluish, N+ crimson pigments.

Within the genus *Japewiella*, *J. pruinosula* is well separated from the other known species as described in Printzen (1999) and James (2009) by the combination of the persistent proper exciple inspersed with crystals, the persistently plane, pruinose apothecial disc, the relatively long and broad ascospores and thallus chemistry; oil paraphyses, although not present in every section studied, also appear to be unique to this species. *Japewiella tavaresiana* differs from *J. pruinosula* chiefly by its smaller apothecia (to 0.5 mm wide) and by containing atranorin only. *Japewiella djagensis* (Zahlbr.) Printzen also differs by its chemistry (atranorin plus two unidentified xanthones and one unidentified depside), as well as by its areolate thallus, its apothecia with convex disc and indistinct excipulum, and by its smaller ascospores (11.5–13.5 × 7–8 µm) (Printzen 1999). The most similar species to *J. pruinosula* appears to be *J. pacifica* Printzen, which like *J. pruinosula* has crystalline inclusions in the thallus and apothecia (Printzen 1999, 2004). However, these granules are soluble in KOH whereas those of *J. pruinosula* are not, and the species differs further by its warted thallus,

apically brown paraphyses and different chemistry (atranorin, chloroatranorin, 3-chlorostenosporic acid, 3-chloroperlatolic acid and 3-chlorodivaricatic acid; Printzen 2004).

Filson (1996) erroneously considered *Buellia rimulata* (Nyl.) Zahlbr., based on an Australian type, to be a synonym of *Lecidea pruinosula* (now *Japewiella pruinosula*), and this synonymy has persisted in subsequent Australian lists. The original description of this species (as *Lecidea rimulata* Nyl.) specifically mentions a saxicolous habitat, black apothecia, a brown to black-brown hypothecium and brown, 1-septate ascospores (Nylander 1864), all characters consistent with its combination in *Buellia* and completely inappropriate for *Japewiella*. Indeed, Bungartz *et al.* (2007) considered *Buellia rimulata* to be a synonym of the widely distributed species *B. stellulata* (Taylor) Mudd.

Acknowledgments

I thank Jean Jarman for the photograph and for preparing Figure 1B for publication, and Jack Elix for assistance with critical chemical data. Much of this study was undertaken at the Botany Department of the Natural History Museum, London, and I thank the Keeper and staff for their support during my visit there.

References

Bungartz, F., Nardin, A. & Grube, M. (2007). *'Buellia'*, in T.H. Nash III, C. Gries and F. Bungartz (eds), *The Lichen Flora of the Greater Sonoran Desert Region*, **Vol. 3**, pp. 113–179. Lichens Unlimited: Tempe.

Ekman, S. (1996). The corticolous and lignicolous species of *Bacidia* and *Bacidina* in North America. *Opera Botanica* **127**, 1–148.

Elix, J.A. and Tonsberg, T. (1999). Notes on the chemistry of some lichens from Norway. *Graphis Scripta* **10**, 4–6.

Elix, J.A., Giralt, M. and Wardlaw, J.H. (2003). New chlorodepsides from the lichen *Dimelaena radiata*. *Bibliotheca Lichenologica* **86**, 1–7.

Filson, R.B. (1996). *Checklist of Australian Lichens and Allied Fungi*. Flora of Australia Supplementary Series 7. Australian Biological Resources Study: Canberra.

Hafellner, J. (1984). Studien in Richtung einer natürlicheren Gliederung der Sammelfamilien Lecanoraceae und Lecideaceae. *Beiheft zur Nova Hedwigia* **79**, 241–371.

Hertel, H. and Rambold, G. (1995). On the genus *Adelalecia* (lichenized Ascomycotina, Lecanorales). *Bibliotheca Lichenologica* **57**, 211–230.

James, P.W. (2009) *'Japewiella* Printzen (1999)', in C.W. Smith, A. Aptroot, B.J. Coppins, A. Fletcher, O.L. Gilbert, P.W. James and P.A. Walseley (eds), *The Lichens of Great Britain and Ireland*, pp. 449–450. British Lichen Society: London.

Kantvilas, G. (1988). A re-examination of John Shirley's collection of Tasmanian lichens. *Papers and Proceedings of the Royal Society of Tasmania* **122(2)**, 59–67.

Kantvilas, G. (2009). The genus *Mycoblastus* in the cool temperate Southern Hemisphere, with special reference to Tasmania. *Lichenologist* **41**, 151–178.

Kantvilas, G., Elix, J.A. & Jarman, S.J. (2008). A contribution to an inventory of lichens from South Sister, northeastern Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* **142**, 49–60.

Lumbsch, H.T. and Huhndorf, S.M. (2007). Outline of Ascomycota - 2007. *Myconet* **13**, 1–58.

Nylander, W. (1864). Circa G.W. Koerberi reliquias Hochstetterianas. *Flora* **47**, 266–270.

Orange, A., James, P.W. and White, F.J. (2001). *Microchemical Methods for the Identification of Lichens*. British Lichen Society: London.

Printzen, C. (1999). *Japewiella gen.* nov., a new lichen genus and a new species from Mexico. *Bryologist* **102**, 714–719.

Printzen, C. (2004). *'Japewiella'*, in T.H. Nash III, B.D. Ryan, P. Diederich, C. Gries and F. Bungartz (eds), *The Lichen Flora of the Greater Sonoran Desert Region*, **Vol. 2**, pp. 138–139. Lichens Unlimited: Tempe.

Tonsberg, T. (1990). *Japewia subaurifera*, a new lichen genus and species from north-west Europe and western North America. *Lichenologist* **22**, 205–212.

Sex discrimination of Buloke (*Allocasuarina luehmannii*) for selective revegetation

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Abstract

Allocasuarina luehmannii (Buloke) is a slow-growing dioecious species occurring primarily in south-eastern Australia. Larger seed-bearing female trees, at least 100 yrs old, are an essential food source for the threatened *Calyptorhynchus banksii graptogyne* (Karak). Sex-discrimination in Buloke was investigated utilising Random Amplified Polymorphic DNA (RAPD) and Inter-Simple Sequence Repeat (ISSR) techniques. While described as a dioecious species, 18% of the plants sampled were monoecious suggesting that this is in fact a subdioecious species. Stem material from 55 paddock trees was collected to identify genetic differences between female, male and monoecious plants. An initial screening of 56 primers, on a subset of five female, five male and five monoecious samples, identified 21 RAPD and 21 ISSR primers with clear scorable bands, but no unique female bands were amplified. Investigation into the sex determination mechanism of this species and the possible effect of environmental factors on sex expression is recommended before further sex-specific marker research is undertaken.

Keywords: sex-linked DNA markers, ISSR and RAPD analysis, subdioecy

Muelleria 29(2): 104-109 (2011)

Introduction

Buloke (*Allocasuarina luehmannii* (R.T.Baker) L.A.S.Johnson) woodland occurs in grassy open forest areas in south-eastern Australia (Department of the Environment, Water, Heritage and the Arts 2010). Vast tracts of this endangered vegetation community have been cleared for agriculture with only 3% of the original cover remaining (EPBC 1999). The endangered Karak or Red-tailed black cockatoo (*Calyptorhynchus banksii graptogyne*) feeds on mature cones of remnant Buloke for a short period each year when its staple food source is not available (Maron & Lill 2004). This has serious implications for the Karak as food availability has been suggested as a factor limiting population size (Maron & Lill 2004). Recently, farmers have set aside profit-making land for the revegetation of Buloke woodland to aid in the protection of the Karak. The propagation and revegetation of this species as a future food source for the Karak presents a number of challenges including an undetermined sex-expression mechanism and difficulty in *ex-situ* propagation.

Buloke is described as a dioecious species (Walsh & Entwistle 1996), so only a proportion of mature trees represent a potential food source. Revegetation with a higher proportion of female trees would concentrate the food source for the Karak in a smaller land area, thus meeting primary production and conservation needs. Females do not reach sexual maturity for ten to fifteen years and thus sexing seed propagated plants before field planting is not practical. The cone-bearing females do not reach a size suitable for Karak feeding for almost 100 years (Maron 2005). Clonal propagation from heavily seed bearing female trees is a possible tool for ensuring higher proportion of female trees in revegetation programs. Cutting propagation has been successful in other species of Casuarinaceae (Kondas 1981). Stem cuttings from the canopies of eight mature female Bulokes failed to strike, although stems harvested from a sucker propagated successfully (Delpratt, Conomikes and Wright, unpub. data). While promising, this solution would result in lower levels of genetic diversity in Buloke plantings in comparison to raising plants from seed. Populations consisting of clonal material from a limited number of parent plants could have decreased fitness levels and greater susceptibility to pests and diseases. Often, this does not

become apparent for several generations, which would be especially problematic in a slow-growing species like Buloke.

The development of a simple cost effective genetic test to distinguish female individuals would allow seedlings to be used as the primary propagule for revegetation with high proportions of females, and thus enhance the genetic diversity in the plantings. There have been a number of studies developing such tests in economically important dioecious plants such as *Salix viminalis* L. (Common Osier) (Alstrom-Rapaport *et al.* 1998), *Carica papaya* L. (Gangopadhyay *et al.* 2007), *Trichosanthes dioica* Roxb. (Pointed Gourd) (Kumar *et al.* 2008) and *Phoenix dactylifera* L. (Date Palm) (Younis *et al.* 2008). The majority of these studies have utilised Inter Simple Sequence Repeat (ISSR) or Random Amplified Polymorphic DNA (RAPD) analysis and occasionally Amplified Fragment Length Polymorphism (AFLP) analysis to identify consistent genetic differences between females and males (and in some cases hermaphrodites). Once consistent differences have been identified by RAPD, ISSR or AFLP, it is possible to convert the amplification products to a simple PCR-based test called Sequence Characterised Amplified Regions (SCAR) to discriminate female plants at the seedling stage (Gunter *et al.* 2003). The use of SCAR markers in plant conservation represents a novel application of this technique.

Interestingly, there have been reports of monoecious trees in small proportions of Wimmera Buloke populations (pers. comm. M. Maron 2009). The presence of both dioecious and monoecious plants in a population, known as subdioecy, is believed to be one of the intermediate sexual systems on the evolution from hermaphroditism (or monoecy) to dioecy (Charlesworth *et al.* 2005; Ming *et al.* 2007). While it is still possible to identify sex-linked genetic differences in subdioecious systems (Chaves-Bedoya & Nuñez 2007), these reports need to be investigated so that all sexual morphs can be included in the initial screen for genetic differences.

The aim of this study was to identify consistent genetic differences between male, female and monecious Buloke plants to allow the female individuals to be distinguished prior to reproductive maturity. To achieve this we began by investigating reports of occasional monoecy in Wimmera populations of Buloke. Secondly, we used RAPD and ISSR techniques to screen for consistent genetic differences between male, female and monoecious plants.

Methods

In December 2008, paddock trees near Edenhope, Victoria (37°3'S, 141°20'E) were investigated to estimate gender ratios and collect stem material for DNA extraction. The gender of 55 trees was distinguished by the presence of staminate flowers (Fig. 1a) for

Figure 1. Morphological characteristics used to assign gender to Buloke plants. 1*a* staminate flowers and 1*b* female cones.

males, seed bearing cones (Fig. 1b) for females or both for monoecious plants. Herbarium specimens were prepared for lodgement in the National Herbarium of Victoria (MEL). In preparation for DNA extraction stems from each plant sampled were stored at -20°C. Then 100 mg of each sample was cleaned with 0.5 mL/L Triton X, followed by a rinse with sterile distilled water, and emersion in 1 mL/L of 20% SDS rinsed with sterile distilled water then crushed to a powder in a mortar and pestle using liquid nitrogen. Qiagen® DNeasy mini kits were used to isolate DNA from each sample according to the manufacturer's instructions. Samples were run on a 1.5% agarose gel containing 1 µL /10 mL Sybrsafe at 110 V for 1.5 hours and visualised using UV light to determine DNA concentration. DNA concentration was standardised to 5 ng/µL before use in RAPD and ISSR reactions.

Each 25 µL RAPD reaction contained 10 ng of DNA, 12.5 µL of GoTaq® Green Master Mix, 0.8 mM of each primer and made to volume with sterile MilliQ® water. RAPD reactions were conducted using a Corbett Thermal Cycler with an initial strand separation cycle of 94°C for two minutes followed by 45 cycles of 94°C for 30 seconds, 34°C for 30 seconds, 72°C for one minute with a final extension of 72°C for five minutes. Five µL of each reaction was loaded on a 2% agarose gel and

Table 1. The ISSR and RAPD primers used in this research.

ISSR Primers	Sequence	RAPD Primers	Sequence
Primers that produce amplification products:			
807	AGA GAG AGA GAG AGA GT	OP81	GTT TCG CTC C
B09	AGA GAG AGA GAG AGA GG	OP820	GGA CCC TTA C
810	GAG AGA GAG AGA GAG AT	OPC11	AAA GCT GCG G
811	GAG AGA GAG AGA GAG AC	OPC16	CAC ACT CCA G
814	CTC TCT CTC TCT CTC TTG	OPD13	GGG GTG ACG A
822	TCT CTC TCT CTC TCT CA	OPH8	GAA ACA CCC C
823	TCT CTC TCT CTC TCT CC	OPQ9	GGC TAA CCG A
824	TCT CTC TCT CTC TCT CG	OPV1	TGA CGC ATG G
840	GAG AGA GAG AGA GAG AYT	OPV2	AGT CAC TCC C
841	GAG AGA GAG AGA GAG AYC	OPV3	CTC CCT GCA A
842	GAG AGA GAG AGA GAG AYG	OPV5	CCC CTC ACG A
844a	CTC TCT CTC TCT CTC TAC	OPV6	ACG CCC AGG T
849	GTG TGT GTG TGT GTG TYA	OPV7	GAA GCC AGC C
850	GTG TGT GTG TGT GTG TYC	OPV8	GGA CGG CGT T
851	GTG TGT GTG TGT GTG TYG	OPV10	GGA CCT GCT G
868	GAA GAA GAA GAA GAA GAA	OPV12	ACC CCC CAC T
8L1	GAG AGA GAG AGA GG	OPV14	AGA TCC CGC C
BL2	GTG TGT GTG TGT GG	OPV15	CAG TGC CGG T
BL3	GAG AGA GAG AGA CC	OPV16	ACA CCC CAC A
8L4	GTG TGT GTG TGT CC	OPV19	GGG TGT GCA G
BL5	CAC CAC CAC GC	OPV20	CAG CAT GGT C
Primers that did not produce amplification products:			
831	ATA TAT ATA TAT ATA TYA	OPA4	AAT CGG GCT G
832	ATA TAT ATA TAT ATA TYC	OPC13	AAG CCT CGT C
833	ATA TAT ATA TAT ATA TYG	OPE16	GGT GAC TGT G
(GA)8N	GAG AGA GAG AGA GAG AN	OPV4	CCC CTC ACG A
(GT)8N	GTG TGT GTG TGT GTG TN	OPV9	TGT ACC CGT C
		OPV11	CTC GAC AGA G
		OPV13	ACC CCC TGA A
		OPV17	ACC GGC TTG T
		OPV1B	TGG TGG CGT T

electrophoresis was conducted for two hours at 110 V. Amplified bands were photographed with a Kodak Digital Science DC120 digital camera and size of bands by molecular weight was determined using a Gene Ruler® 100 base pair (bp) ladder as a reference (MBI Fermentas, Germany) with Kodak Digital Imaging® software. ISSR reactions were conducted as for the RAPD analysis using the cycle: 94°C for three minutes followed by 35 cycles of 94°C for 30 seconds, 50°C for 30 seconds, 72°C for one minute with a final extension of 72°C for ten minutes.

An initial screening of 26 ISSR and 30 RAPD primers (Table 1) was conducted using a single female DNA sample. The initial screening primers were selected from those shown to be successful for *Allocasuarina* species (Yasodha *et al.* 2004) and in the sex discrimination of other dioecious plants including *Salix viminalis* (Alstrom-Rapaport *et al.* 1998), *Carica papaya* (Gangopadhyay *et al.* 2007), *Trichosanthes dioica* (Kumar *et al.* 2008) and *Phoenix dactylifera* (Younis *et al.* 2008). Primers that produced clear bands in the initial screen were used to test for consistent genetic differences between five female, five male and five monoecious plants from site one. The ISSR primer BL4 was run with an extended sample set of 18 female, 18 male and 4 monoecious samples.

Results

Among the trees sampled were 23 female (42%), 22 male (40%) and 10 monoecious (18%) individuals. The initial screening of 56 primers resulted in 21 RAPD and 21 ISSR primers with clearly amplified bright bands (Table 1). The selected 21 RAPD and 21 ISSR primers were run with DNA from five male, five female and five monoecious plants. The ISSR analysis produced a total of 1044 bands ranging from 100 bp to 1200 bp in size, 474 of which were polymorphic (45%). The RAPD analysis produced 284 bands from 100 bp to 1500 bp in size, 209 of which were polymorphic (74%). In all cases where primers produced amplification products, bands were produced in at least one of each of the female, male and monoecious samples. There were no instances where bands were amplified in only one sex and none of the primers amplified a reproducible band unique to the female samples. The ISSR primer BL4 showed some promise, as it produced faint bands unique to three of five female samples in the first screening. However, when ISSR reactions were run with primer BL4 and an expanded DNA sample set from female (18), male (18) and monoecious (4) plants, no unique female markers were generated.

Discussion

Though *Allocasuarina luehmannii* is documented as a dioecious species (Walsh & Entwistle 1996) 18% of the samples collected had evidence of both staminate stems and female cones. This is an unusually high proportion of monoecious individuals in a population of dioecious species from the Casuarinaceae, with 2-3% monoecious individuals reported in *Casuarina equistifolia* L. (Yasodha *et al.* 2004) and less than 1% previously observed in nearby Wimmera *A. luehmannii* populations (pers. comm. Martine Maron 2010). The presence of monoecious plants in *A. luehmannii* populations suggests that this species is subdioecious rather than dioecious. Studies of the reproductive viability of the monoecious individuals are required to confirm this characterisation, as it is still unknown whether these plants produce both viable pollen and ovules. Comparing the amount of seed produced and cone size of monoecious and female plants, alongside investigations of feeding preferences between these sexual morphs, would help elucidate whether these plants represent a significant food source for the Karak.

Dioecy is relatively rare among flowering plants (Yampolsky & Yampolsky 1922; Renner & Ricklefs 1995). It is widespread across different lineages and is therefore believed to have evolved repeatedly, although usually within a single species (Westergaard 1958; Meagher 2007). However, dioecy is prevalent in some families such as the Salicaceae, Euphorbiaceae, Cucurbitaceae and the Casuarinaceae. The genetic basis of sex determination in flowering plants is variable (Irish & Nelson 1989), with genetic mechanisms ranging from a single locus on an autosomal chromosome to the presence of heteromorphic X and Y chromosomes containing multiple genes involved in sex determination (Ming *et al.* 2007). A higher proportion of sex-specific markers are expected in the presence of X and Y chromosomes as, due to the difference in chromosomes between males and females, there are a larger number of sex-specific genes in this system. The genetic mechanism for sex determination in the Casuarinaceae

is still unknown. The Casuarinaceae originated outside of Australia and non-Australian species have retained a fairly stable diploid chromosome number (Barlow 1959). Those species endemic to Australia have highly variable, often polyploid chromosome numbers (Barlow 1959). *Allocasuarina luehmannii* is one of the few tetraploid species ($2n = 56$) in the family.

No sex-specific markers were identified in *A. luehmannii* by this study (26 ISSR and 30 RAPD primers) or in *Casuarina equistifolia* by Yasodha *et al.* (2004) who screened 7 ISSR primers on DNA from 12 individuals. With the presence of X and Y sex chromosomes a relatively high number of sex-specific markers would be expected using ISSR and RAPD methods. This suggests that sex determination in Buloke, and in other members of the Casuarinaceae, is not due to the presence of X and Y sex chromosomes.

Given the variability of the genetic basis for sex determination in flowering plants it is not surprising that studies that have successfully identified sex-specific markers have required widely differing numbers of primers to successfully identify consistent differences between males and female plants; *e.g.* 15 RAPD for *Cannabis sativa* L., a dioecious species that has X and Y sex chromosomes (Sakatmoto *et al.* 1995) and 1,000 RAPD primers for *Salix viminalis* that appears to lack X and Y chromosomes (Gunter *et al.* 2003). It is possible that screening more primers than those used in the current study (*e.g.* >1,000) may identify sex-specific markers in Buloke, but other molecular methods may prove to be more useful. One such method, AFLP analysis, has been shown to produced a higher number of polymorphic bands per primer when compared to RAPD analysis (*i.e.* Sharma *et al.* 1996), thus increasing the likelihood of identifying a sex-specific markers.

In some plant species such as cucumber and maize sex expression is influenced by environmental factors such as light intensity, day length, temperature, mineral nutrition and plant hormones (Frankel & Galun 1977; Tandudzic & Banks 2004). It is important to establish whether or not one of these regulatory signals operates in the sex determination of Buloke plants. The identification of sex-specific markers may not give an accurate diagnosis of plant sex when external influences are involved, especially if plants are exposed to artificial growth environments such as nursery containers and glasshouses. Monitoring of sex ratios in multiple geographically widespread Buloke populations over a number of seasons may help to reveal whether changes in gender do occur. More direct studies exposing reproductively mature male, female and monoecious plants to different environmental conditions and plant hormone treatments under controlled conditions would help to elucidate what, if any, environmental factors influence sex expression in Buloke.

Further research into the sex determination mechanism in Buloke is recommended as it would help to predict the research effort required to locate sex-specific markers. In some sex determination systems such as XX:XO, where sex expression is influenced by dosage of the X chromosome rather than different genetic information (Hodgkin 2002), it is not possible to locate sex-specific markers. This system has not yet been described in plants. As there is no information on sex determination in the Casuarinaceae it is not possible that such a system could be responsible.

The aim of this project was to find genetic markers that can consistently identify female plants prior to fruiting. The use of RAPD and ISSR methods for this purpose relies on randomly locating sex-associated DNA regions. While the use of a wider range of RAPD and ISSR primers may achieve the above aim, it is unlikely that sex determination in Buloke is based on the presence of X and Y chromosomes, thus lacking the relatively large number of sex-specific regions of DNA that characterise this system. Therefore, we suggest that a much larger number of RAPD and ISSR primers and/or range of molecular methods is necessary in further studies to identify sex-specific markers in Buloke. It is also important to investigate the effect of environmental factors on sex expression and the genetic basis of sex determination in Buloke as these findings may make the identification of sex-specific markers redundant. In the mean time, the enhancement of revegetation plantings with high-bearing female trees will depend on refining clonal propagation techniques such as cutting propagation, micropropagation and the inducement of root suckers from selected paddock trees.

Acknowledgments

This study has been generously funded by the Kowree Tree Farm Group. We would also like to acknowledge the information from Martine Maron of The University of Queensland on sex ratios in Buloke paddock trees.

References

Alstrom-Rapaport, C., Lascoux, M., Wang, Y., Roberts, G. and Tuskan, G. (1998). Identification of a RAPD marker linked to sex-determination in the 8asket Willow (*Solix viminolis* L.). *Journal of Heredity* **89**, 44-49.

Barlow, B. (1959). Chromosome numbers in the Casuarinaceae. *Australian Journal of Botany* **7**(3), 230-237

Chaves-8edoya, G. and Nuñez, V. (2007). A SCAR marker for the sex types determination in Colombian genotypes of *Corico papoyo*. *Euphytico* **153**, 215-220.

Charlesworth, D., Charlesworth, B. and Marais, G. (2005). Steps in the evoluation of hetermorphic sex chromososmes. *Heredity* **95**, 118-128.

Department of the Environment, Water, Heritage and the Arts (2010). 8uloke Woodlands of the Riverina and Murray-Darling Depression Bioregions in Community and Species Profile and Threats Database. Department of the Environment, Water, Heritage and the Arts: Canberra.

Environment Protection and Biodiversity Conservation (1999). *Environment Protection and Biodiversity Conservation Act*, Commonwealth of Australia: Canberra.

Frankel, R. and Galun, E. (1977). *Pollinotion mechanisms, reproduction ond plant breeding*. Springer-Verlag: Berlin, Germany.

Gangopadhyay Roy, S.K., Ghose, K., Poddar, R., Bandyopadhyay, T., Basu, D. and Mukherjee, K.K. (2007). Sex determination of *Carica papoya* and *Cycas circinalis* in pre-flowering stage by ISSR and RAPD. *Current Science* **92**, 524-526.

Gunter, L.E., Roberts, G.T., Lee, K., Larimer, F.W. and Tuskan, G.A. (2003). The development of two flanking SCAR markers linked to a sex determination locus in *Salix viminalis* L. *Journol of Heredity* **94**, 185-189.

Hodgkin, J. (2002). Exploring the Envelope: Systematic Alteration in the Sex-Determination System of the Nematode *Caenorhabditis elegans*. *Genetics* **162**, 767-780

Irish, E. and Nelson, T. (1989). Sex determination in monoecious and dioecious plants. *The Plant Cell* **1**, 737-744.

Kondas, S. (1981). 'Mist tent propagation of *Cosuorino junghuhniona*', in Midgley, S.J., Turnbull, J.W. and Johnston, R.D. (eds.), *Casuarina Ecology Monagement ond Utilizotion: Proceedings of an International Workshop*, p. 135. Canberra: Australia.

Kumar, S., Singh, 8.D., Sinha, D.P. and Rai, M. (2008). 'Sex expression-assoicated RAPD markers in pointer gourd (*Trichosonthes dioica*)' in M. Pitrat (ed.), *Cucurbitaceoe 2008, Proceedings of the IXth EUCARPIA meeting on genetics and breeding of Cucurbitaceoe*. Institut National de la Recherche Agronomique: Avignon, France.

Liao, L., Liu, J., Dai, Y., Li, Q., Xie, M., Chen, Q., Yin, H., Qiu, G., Liu, X. (2009). Development and application of SCAR markers for sex identification in the dioecious species *Ginkgo bilobo* L. *Euphytica* **169**, 49-55.

Maron, M. and Lill, A. (2004). Discrimination among potential buloke (*Allocasuarina luehmonnii*) feeding trees by the endangered south-eastern red-tailed black-cockatoo (*Calyptoryhnchus banksii groptogyne*). *Wildlife Research* **31**(3), 311-317.

Maron, M. (2005). Agricultural change and paddock tree loss: Implications for an endangered subspecies of Red-tailed Black-Cockatoo. *Ecological Management & Restoration* **6**(3), 206-211.

Meagher, T. (2007). Linking the evolution of gender variation to floral development. *Annals of Botony* **100**, 165-176.

Ming, R., Wang, J., Moore, P.H. and Paterson, A.H. (2007). Sex chromosomes in flowering plants. *Americon Journal of Botany* **94**(2), 141-150.

Paranis, A.S., Gupta, V.S., Tamhankar, S.A. and Ranjekar, P.K. (1999). A highly reliable sex-diagnostic PCR assay for mass screening of papaya seedling. *Moleculor Breeding* **63**, 337-344.

Renner, S.S. and Ricklefs, R.E. (1995). Dioecy and its correlates in flowering plants. *American Journal of Botany* **82**, 596-606.

Sakatmoto, K., Shuimomura, K., Komeda, Y., Kamada, H. and Satoh, S. (1995). A male-associated DNA sequence in a dioecious plant, *Connabis sativo* L. *Plont ond Cell Physiology* **36**, 1549-1554.

Sharma, S.K., Knox, M.R. and Ellis T.H.N. (1996). AFLP analysis of the diversity and phylogeny of *Lens* and its comparison with RAPD analysis. *Theoretical and Applied Genetics* **93**, 751-758

Tandudzic, M. and Banks, J.A. (2004). Sex-determining mechanisms in land plants. *The Plant Cell* **16**, S61-S71.

Walsh, N.G. and Entwistle, T.J. (1996). *Flora of Victoria* **3**. Inkata Press: Melbourne.

Westergaard, M. (1958). The mechanisms of sex determination in dioecious flowering plants. *Advonces in Genetics* **9**, 217-281.

Yampolsky, C. and Yampolsky, H. (1922). Distribution of the sex forms in the flora. *Bibliotheca Genetica* **3**, 1-62.

Yasodha, R., Kathirvel, M., Sumathi, R., Gurumurthi, K., Archak, S. and Nagaraju, J. (2004). Genetic analysis of Casuarinas using ISSR and FISSR markers. *Genetico* **122**, 161-172.

Younis, R., Ismail, O. and Suliman, S. (2008). Identification of sex-specific DNA markers for Date Palm (*Phoenix doctylifera* L.) using RAPD and ISSR techniques. *Research Journal of Agriculture and Biologicol Sciences* **4**(4), 278-284.

Resolution of the *Thelymitra aristata* (Orchidaceae) complex of south-eastern Australia

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Abstract

The seven currently known taxa in the *Thelymitra aristata* Lindl. complex are reviewed and descriptions are presented for each. *Thelymitra adorata* Jeanes and *Thelymitra kangaloonica* Jeanes from eastern New South Wales are described as new and illustrated. The key diagnostic features relating to the size and colour of the perianth, the shape of the post-anther lobe of the column, the presence or absence of auxiliary lobes, the density of the hairs on the lateral lobes and the placement of the anther are elucidated. Information on distribution, habitat, pollination biology, flowering time and conservation status is given for all seven taxa. The main distinguishing features of *Thelymitra aristata*, *Thelymitra epipactoides* F.Muell., *Thelymitra grandiflora* Fitzg., *Thelymitra planicola* Jeanes, *Thelymitra silena* D.L.Jones and the two new species are tabulated. A key is provided to distinguish all seven members of the *T. aristata* complex.

Keywords: sun orchids, taxonomy, diagnostic features

Muelleria 29(2): 110-129 (2011)

Introduction

Thelymitra J.R.Forst. & G.Forst. is a complex genus of orchids consisting of about 100 described species, several described natural hybrids and at least 10 undescribed taxa. It is concentrated in higher rainfall areas of temperate Australia, but a few species occur in tropical north-eastern Australia, about 20 species occur in New Zealand (15 endemic) and a few species occur in Indonesia, New Caledonia, New Guinea and the Philippines.

This is one of a series of papers by the author reviewing the various morphologically distinct groups or complexes within *Thelymitra*. During the course of my studies of the *Thelymitra aristata* Lindl. complex it became evident that two undescribed species were present within the group. I take this opportunity to describe these new species and review the entire complex.

There are a number of morphological features that, in combination, distinguish members of the *Thelymitra aristata* complex from all other *Thelymitra* species. Plants are generally robust and fleshy with the inflorescence often 40–100 cm tall. The leaf and sterile bracts are also usually large and fleshy. The flowers are often numerous, large to moderately large, usually pale blue to deep blue but may be purplish or mauve (or pink, green, reddish or brownish in *Thelymitra epipactoides* F.Muell.), scented or unscented. The column has a well-developed post-anther lobe that may be more or less rectangular and strap-like or with the lateral margins variously recurved. Auxiliary lobes are absent, except in *T. epipactoides*. The lateral lobes are well-developed (except in *T. silena*) with dense terminal tufts of white hairs (sparse or absent in *T. silena*). The anther may be basal or produced about half way along the column at anthesis. Although the flowers are generally large for the genus and open fairly freely in warm weather some species are apparently insect-pollinated while others are facultatively autogomous.

Taxonomic history and discussion

Historically there has been significant confusion about the correct application of names and the interpretation of species within the

T. aristata complex, most notably with *T. aristata* itself. This confusion persisted for more than 100 years and has revealed itself in the many floras and orchid books published during that time. It was only relatively recently, following the study of the type material, that the correct application of names was finally achieved.

The first species in the group to be recognised, *T. aristata*, was described by Lindley (1840) from two R. Gunn collections from far north-western Tasmania. The type specimens are accompanied by a very rudimentary line drawing, apparently executed by Lindley, of a column in profile, which unfortunately gives the impression of a tubular post-anther lobe. Lindley's Latin diagnosis does not help to establish the morphology of the post-anther lobe although he clearly knew it differed from that of members of the *Thelymitra nuda* R.Br. and *Thelymitra pauciflora* R.Br. complexes as species belonging to these are listed separately in his publication. Hooker (1858) reduced *T. aristata* to synonymy under Robert Brown's *Thelymitra angustifolia* R.Br., probably as a result of his misinterpretation of the latter species or of the Lindley sketch on the type sheet of *T. aristata*. Mueller (1866) described *T. epipactoides* based on two fragmentary specimens collected by C. French junior from the Port Phillip region of Victoria. He compared his new species to *Thelymitra canaliculata*

Table 1. Taxonomic history of the *T. aristoto* complex showing the names used by various authors for the seven taxa recognised in the current treatment.

Author	Name used						
Lindley (1840)	*T. aristata*	n/a	n/a	n/a	n/a	n/a	n/a
Hooker (1858)	*T. angustifalia*	n/a	n/a	n/a	n/a	n/a	n/a
Mueller (1866)	*T. aristata*	*T. epipoctoides*	n/a	n/a	n/a	n/a	n/a
*Bentham (1873)	none	*T. ixiaides* or *T. conoliculoto*	n/a	n/a	n/a	n/a	n/a
*Mueller (1882)	none	none	n/a	n/a	n/a	n/a	n/a
Fitzgerald (1882)	none	none	*T. grandiflara*	n/a	n/a	n/a	n/a
*Mueller (1886)	none	*T. epipoctoides*	nane	n/a	n/a	n/a	n/a
*Fitzgerald (1875–1894)	nane	*T. epipoctoides*	*T. grondifloro*	n/a	n/a	n/a	n/a
*Ewart (1930)	*T. grondifloro* p.p.	*T. epipoctaides*	*T. grandiflara* p.p.	n/a	n/a	n/a	n/a
Nicholls (1934)	*T. murdochae* *T. grondifloro*	nane	none	n/a	n/a	n/a	n/a
*Black (1943)	*T. grondifloro* p.p.	*T. epipoctoides*	*T. grandiflora* p.p	n/a	n/a	n/a	n/a
*Willis (1962)	*T. grondiflaro* p.p.	*T. epipoctoides*	*T. grondiflaro* p.p.	n/a	n/a	n/a	n/a
*Nicholls (1969)	*T. murdochoe* *T. grandiflora* p.p.	*T. epipactoides*	*T. grondifloro* p.p.	n/a	n/a	n/a	n/a
George (1971)	*T. oristoto*	none	*T. oristoto*	n/a	n/a	n/a	n/a
Jones (1988)	*T. aristoto*	*T. epipoctoides*	*T. oristoto*	n/a	n/a	n/a	n/a
Clements (1989)	*T. aristoto*	*T. epipoctaides*	*T. oristoto*	n/a	n/a	n/a	n/a
Bates & Weber (1990)	*T. oristota*	*T. epipoctoides*	*T. oristoto*	n/a	n/a	n/a	n/a
Weber & Entwisle (1994)	*T. oristato*	*T. epipoctaides*	*T. grondifloro*	n/a	n/a	n/a	n/a
Backhouse & Jeanes (1995)	*T. oristoto*	*T. epipoctoides*	*T. oristoto*	n/a	n/a	n/a	n/a
Jones (1999)	*T. oristota*	none	*T. grandiflaro*	*T. sileno*	n/a	n/a	n/a
Bishap (2000)	*T. oristota*	*T. epipactoides*	nane	none	n/a	n/a	n/a
Janes (2006)	*T. oristota*	*T. epipoctoides*	*T. grondifloro*	*T. sileno*	*T. plonicala*	*T. adarota ms*	*T. kangaloonica ms*
Jeanes (this paper)	*T. oristoto*	*T. epipoctoides*	*T. grondifloro*	*T. silena*	*T. planicolo*	*T. adaroto*	*T. kangoloonica*

*The name *T. aristata* is used in the publication but is incorrectly applied to taxa outside this complex

Table 2. Various features of species in the *T. aristata* complex.

	T. aristata	*T. epipactaides*	*T. grandiflara*	*T. silena*	*T. adarata*	*T. kangaloanicaa*	*T. planicala*
Height of inflorescence (cm)	20–100	20–50	20–80(–100)	20–55	20–60	20–56	22–45
Number of sterile bracts	1–4	1 or 2	2–4	usually 2	2–4	2–3	2–4
Number of flowers per inflorescence	2–40	6–25	2–30	3–15	2–13	2–15	2–12
Usual colour of flowers	blue to violet	pink, bronze, green, blue or reddish	blue, lilac, mauve or pale purplish, rarely pink,	pale blue	dark blue	dark blue with darker longitudinal veins	medium blue with darker blue longitudinal veins
Length of sepals (mm)	10–25	12–20	8–20	10–19	8–13	8–18	7–15
Shape of post-anther lobe extension	flat to curved and strap-like	more or less flat and strap-like	straight to curved, strap-like, base thick, lateral margins often decurved	more or less globose, apex deeply bilobed, lobes irregularly toothed	curved, more or less semicylindric, apex notched, distal margin irregularly toothed, incurved	curved, more or less flat, strap-like, apex notched, distal margin toothed or incised;	curved, more or less semicylindric, apex shallowly bilobed, distal margin irregularly toothed
Auxiliary lobes of column	absent	present	absent	absent	absent	absent	absent
Length of lateral lobes of column (mm)	1.5–2.5	1–1.5	1.5–2.5	0–1	1.5–2	1.5–2.3	1.2–2
Hairs on lateral lobes of column	dense, more or less terminal	dense, toothbrush-like	dense, more or less terminal	sparse, more or less terminal, or absent	dense, more or less terminal	dense, more or less terminal	dense, more or less terminal
Length of post-anther lobe extension (mm)	1.5–2.5	1–2	2–2.5	2–2.5	1–1.5	1.5–2	0.5–1.2
Anther position at anthesis	basal	basal	basal	mid-way along column	mid-way along column	basal	mid-way along column
Flower scent	present	none reported	present	none reported	none reported	present	none reported
Primary pollination mechanism	entomophily	entomophily	entomophily	autogamy	autogamy	autogamy	autogamy

R.Br. and *Thelymitra media* R.Br. apparently due to the presence of auxiliary lobes on the column. Mueller (1866) also compared the habit of his new species with that of *T. aristata* suggesting that his interpretation of the latter may have been correct. Bentham (1873) recognised *T. aristata* as distinct, but his interpretation of the species appears to have been similar to that of Hooker rather than that of Lindley as he compared it to *Thelymitra longifolia* J.R.Forst. & G.Forst. and *Thelymitra macrophylla* Lindl., both of which belong to a different group. He also attributed it to Western Australia, but it is now known to be confined to eastern Australia. Until very recently most authors followed Hooker or Bentham by erroneously interpreting *T. aristata* as belonging to either the *T. pauciflora* or the *T. nuda* complexes, taxa with a strongly tubular post-anther lobe on the column. Bentham (1873) also did not recognise *T. epipactoides* as distinct, but suggested that it may be a variety of *Thelymitra ixioides* Sw. or *T. canaliculata* probably due to the presence of auxiliary lobes on the columns of those species. Mueller (1882) followed Bentham (1873) in not recognising his own *T. epipactoides*, but later (Mueller 1886) he again recognised *T. epipactoides* as distinct. Fitzgerald (1882) described *Thelymitra grandiflora* Fitzg. from three specimens that he collected in the Mount Lofty Ranges in South Australia. This was soon to become the accepted name for plants from south-eastern Australia with a more or less strap-like post-anther lobe on the column (i.e. Lindley's *T. aristata*). Nicholls (1934) described *Thelymitra murdochiae* Nicholls apparently from a single specimen discovered by E.H. Homann near Wonthaggi in Victoria, a taxon later recognised as a teratological form of *T. aristata*. Nicholls (in Black 1943) reduced *Thelymitra megcalyptra* Fitzg. to varietal rank under *T. aristata* (i.e. *Thelymitra aristata* var. *megcalyptra*) thereby increasing the confusion regarding the true identity of *T. aristata*.

Following his study of the type specimens, George (1971), was probably the first person in nearly 100 years to use the correct application of the name *T. aristata* to the robust species with the strap like post-anther lobe from south-eastern Australia. George (1971) also reduced *T. grandiflora* to synonymy under *T. aristata*. Clements (1989) followed George (1971) in the application of the name *T. aristata* and he also relegated *T. grandiflora* and *T. murdochae* to synonymy thereunder.

Jones (1999) described *Thelymitra silena* D.L.Jones from Clarke Island in Bass Strait, a species later found in several other locations on mainland Tasmania as well as on South Bruny Island. In my original description of *Thelymitra planicola* Jeanes (Jeanes 2000) I commented on the difficulty in placing this species due to the intermediate morphology of the post-anther lobe between those of *T. aristata* and *T. pauciflora sens. lat.* Later (Jeanes 2004) I included *T. planicola* in my treatment of the *T. pauciflora* complex with some uncertainty, and I now believe that it is better placed in the *T. aristata* complex (for an explanation see comments under *T. planicola* below). Jones (2006) for the first time described and circumscribed correctly all seven species in the complex including informal descriptions of *Thelymitra adorata* Jeanes and *Thelymitra kangaloonica* Jeanes, two new species from New South Wales whose names are validated in this paper.

Explanation of the terminology used

The genus *Thelymitra* is unusual in the Orchidaceae in that the six perianth segments generally differ very little from each other in terms of size, shape and ornamentation. The labellum does not bear any hairs, calli, glands, ridges, lobes, teeth or fringes and is apparently not involved in pollination. Since the perianth is virtually actinomorphic and generally lacks characters by which to distinguish the species, traditionally the structure of the column has supplied most of these distinguishing characters. Over the years a terminology has evolved to describe the column structure in *Thelymitra*, but some of these terms are poorly understood and some have never been defined adequately. Below is an explanation of some of the terms commonly used in this paper; most have a traditional usage, although this has often not been well understood.

Column (gynostemium): The column is exposed in the centre of the flower, it lacks a free filament and style, is short and thick and broadly winged from below the stigma to the level of the anther or beyond. The apex is usually 3–5-lobed and is often ornamented with hairs, fringes, teeth, calli, glands, tubercles or lobes. In members of the *T. aristata* complex the apex of the column extends well beyond the point of insertion of the lateral lobes into a well-developed post-anther lobe.

Post-anther lobe (mid-lobe): This structure protrudes

beyond the point of insertion of the anther and of the lateral lobes, and it is usually of a different colour to the rest of the column. It has a complex vascular supply always associated with that of the functional anther and may be regarded as an outgrowth of the filament. In some species it is represented only by a short flap or a band of small calli crowded across the back of the anther. In most species it extends well beyond the anther with a free margin that may be plain, undulate, toothed, notched or variously ornamented with tubercles. At its maximum development it forms a fleshy, tubular hood that is variously open on the ventral side and overhangs and obscures the anther. In the *T. aristata* complex the post-anther lobe is well-developed and may be relatively flat and strap-like or have the lateral margins variously recurved. The apex is often irregularly toothed and notched in the middle and the distal margin may be flat or recurved.

Post-anther lobe extension: This term is used herein for the region of the post-anther lobe that extends beyond the point of insertion of the lateral lobes. The size and shape varies considerably from taxon to taxon and is very useful in helping to define species.

Lateral lobes (column-arms or lateral staminodes): These two structures are inserted one on each side of the post-anther lobe and extend forward or upward and often converge. They are each supplied by a single unbranched vascular bundle and are thought to represent staminodes. They may be flat and ribbon-like, terete and finger-like, straight, curved, twisted spirally or bent sharply, and are usually ornamented with lobes, teeth, tubercles or hairs. The lateral lobes are generally flat and more or less straight in members of the *T. aristata* complex, and each is terminated by a dense mop-like tuft of white hairs. *Thelymitra silena* may completely lack lateral lobes and/or hair tufts or these may be much reduced.

Auxiliary lobes (accessory lobes or side lobules): Several species of *Thelymitra* have a pair of distinct lobes between the post-anther lobe and the lateral lobes. These have no vascular strand and are most accurately described as being part of a tripartite post-anther lobe. They tend to be fleshy with irregularly jagged margins and sometimes have small surface tubercles. In the *T. aristata* complex they are only present in *T. epipactoides* and are strap-like, often strongly incurved and irregularly toothed at the apex.

Anther: In *Thelymitra*, the anther is usually small, ovoid, and situated entirely between the column wings. The connective extends beyond the pollinia into an apical beak-like projection of varying size. The anther may be entirely above the stigma or variously obscured behind it. In the *T. aristata* complex the anther may be inserted basally behind the stigma or about half way along the column at anthesis. The anther beak is small and insignificant.

Pollinia: Members of the genus *Thelymitra* contain four pollinia in two groups of two. In the *T. aristata* complex the pollen grains may be tightly bound with the pollinarium being removed by insects as a single unit, or in some species the pollen is friable leading to autogamy.

Stigma: The stigma in *Thelymitra* is more or less bilobed at the apex, usually quadrate or transverse-elliptic in shape and located at the base of the column on a thick stalk.

Materials and Methods

This paper is the result of a qualitative and quantitative study of the pertinent type material (or photographic reproductions thereof), hundreds of herbarium specimens (both dry and spirit-preserved) from AD, BM, BRI, CANB, E, HO, MEL, NSW, P, PERTH, QRS, SUNIV and WELT, and numerous freshly collected specimens, all of which were vouchered and deposited at the relevant herbaria. Orchid taxa in general, and *Thelymitra* taxa in particular, are much more readily identified from fresh living material where characters of the perianth, the column, flower colour and fragrance are still intact. Familiarity with the taxa gained from field study and the study of freshly collected specimens sent to me by field operatives has made the identification of dried and spirit-preserved herbarium material (including type specimens) much easier.

When collecting *Thelymitra* for study it is essential that the entire above ground parts of the plant be taken, with the majority of the material being preserved in spirit. Plants preserved in the pressed state are often difficult to identify to species level in the absence of additional information. Spirit preserved specimens on the other hand, are generally much more easily identified to species level. The observation of plants growing *in-situ* is the ideal method of study for *Thelymitra* in general, and

often it is only by this method that cryptic new species can be identified. For this reason the importance of field work in the study of species complexes within *Thelymitra* cannot be overstated and should form an integral part of any future studies of the group. It is possible that other taxa worthy of recognition exist within this complex, but adequate information and collections of these are lacking at present.

Taxonomy

1. *Thelymitra epipactoides* F. Muell., *Fragm.* 5: 174 (1866).

***Type*:** Port Phillip, *C. French jun. s.n.* (lectotype MEL 677565!, spirit MEL2039616!, *hic designatus*).

Illustrations: Nicholls (1969) plate 35; Bates & Weber (1990) plates 206 & 207; Backhouse & Jeanes (1995) page 338; Bishop (2000) plate 51; Jeanes & Backhouse (2006) page 198; Jones (2006) page 239.

Glabrous terrestrial *herb*. *Tubers* ovoid, 1–3 cm long, 5–15 mm wide, fleshy. *Leaf* linear-lanceolate to lanceolate, 18–30 cm long, 14–30 mm wide, erect, canaliculate, fleshy, dark green with a reddish base, ribbed abaxially, sheathing at base, apex acuminate. *Inflorescence* 20–50 cm tall. *Scape* 2–6 mm diam., stout, straight, green or purplish. *Sterile bracts* 1 or 2, linear-lanceolate to lanceolate, 5–14 cm long, 5–25 mm wide, leaf-like, green to purplish, closely sheathing at base, acuminate. *Fertile bracts* ovate-acuminate to obovate-acuminate, 2–5 cm long, 4–9 mm wide, sheathing the pedicels, green to purplish. *Pedicels* 4–20 mm long, slender. *Ovary* cylindric to narrow-obovoid, 6–14 mm long, 1.5–4 mm wide. *Flowers* 6–25, 25–42 mm across, pink, bronze, green, blue or reddish, often with a coppery sheen, opening freely in warm weather. *Perianth segments* 12–20 mm long, 4–10 mm wide, thick-textured, concave, often shortly apiculate; *dorsal sepal* ovate, obtuse to subacute; *lateral sepals* ovate

Key to the known members of the *T. aristata* complex.

1 A prominent pair of auxiliary lobes present between the post-anther lobe and the lateral lobes of the column ..... **1. *T. epipactoides***

1: Auxiliary lobes absent **2**

2 Anther inserted well above base of column at anthesis, not or only partially obscured behind the stigma **3**

2: Anther inserted at base of column at anthesis, mostly obscured behind the stigma **5**

3 Lateral lobes of column often poorly developed or absent, if present then hairs sparse or absent; post-anther lobe of column sub-globose; flowers pale blue; Tasmania ..... **2. *T. silena***

3: Lateral lobes of column well-developed, each with a dense terminal tuft of hairs; post-anther lobe of column semi-cylindric; flowers deep blue; New South Wales and Victoria **4**

4 Post-anther lobe of column deeply and narrowly lobed or split at the apex; plants not noticeably glaucous; New South Wales near Gosford ..... **5. *T. odoroto***

4: Post-anther lobe of column not as above; plants glaucous; eastern Victoria and New South Wales between Nowra and Sydney ..... **7. *T. planicola***

5 Perianth segments <20 mm long; flowers opening tardily; plant moderately robust, to 56 cm tall; habitat moderately high altitude sedge-swamp margins; New South Wales ..... **6. *T. kongoloonica***

5: Perianth segments >20 mm long for at least somes flowers in larger individuals; flowers opening freely; plants often very robust, to 100 cm tall; habitat low to moderately high altitude heathlands and heathy woodlands; south-eastern Australia **6**

6 Post-anther lobe of column more or less flat, not thickened at base, lateral margins not, or only slightly recurved; south-eastern Australia ..... **3. *T. aristata***

6: Post-anther lobe of column thickened at the base, lateral margins often strongly recurved; South Australia ..... **4. *T. grandiflora***

to ovate-lanceolate, often slightly asymmetric, acute; *petals* ovate, obtuse to acute; *labellum* ovate to ovate-lanceolate, often narrower than other segments, acute to obtuse. *Column* erect from the end of ovary, 5–8 mm long, 2.3–4.5 mm wide, same colour as perianth but often paler; *post-anther lobe* not hooding the anther, 2–3 mm long, 1–1.5 mm wide; *post-anther lobe extension* 1–2 mm long, more or less flat, strap-like, gently incurved, reddish brown, often with a narrow purplish collar, apex irregularly toothed, yellow; *auxiliary lobes* usually incurved and often interlocking, 1–1.7 mm long, 0.7–1.5 mm wide, more or less flat, strap-like, base reddish brown, apex irregularly toothed, yellow; *lateral lobes* converging, 1–1.5 mm long, digitiform, obliquely erect, each with a toothbrush-like arrangement of white hairs along most of their length, the individual hairs 1–2 mm long. *Anther* inserted at base of column, mostly obscured behind stigma, ovate, 3.5–4.5 mm long, 2–2.5 mm wide, connective produced into a beak 0.5–1 mm long; *pollinarium* c. 3.5 mm long; *viscidium* more or less round, c. 0.5 mm diam.; *pollinia* coherent, white. *Stigma* situated at base of column, ovate-quadrate, c. 2.5 mm long, c. 2.5 mm wide, margins irregular. *Capsules* obovoid, 13–18 mm long, 5–7 mm wide, erect, ribbed. (Fig. 1 a, Fig. 5 a–c)

***Selected specimens examined*: SOUTH AUSTRALIA**: c. 2 miles E of Tintinara, beside main highway, 28.ix.1961, *J.H. Willis s.n.* (MEL 221702); Eyre Peninsula District: c. 3 km N of Wangary, adjacent to Duck Lake, 28.ix.1986, *M.A. Clements 4290* (CANB 8605435); Killanoola, 3.x.1964, *D. Hunt 2152* (AD DH2152);

Figure 1.
a. *Thelymitra epipactoides*;
b. *Thelymitra silena*;
c. *Thelymitra aristata*;
d. *Thelymitra grandiflora*.
(photographs a-c. Jeff Jeanes, RBG Melbourne; d. Mark Clements, CSIRO Canberra)

South-east District, ix.1991, (AD 290595); Yorke Peninsula District: Port Vincent, 28.viii.1976, *R.J. Bates s.n.* (AD RJ8YP); Coonalpyn, 1.ix.2001, *K. Alcock JAJ1020* (MEL 2143258); South-east District: Big Heath National Park; Red Gum Flat, 4.xi.1969, *C.R. Alcock 2977* (AD 97005169); South-east District: Mt Scott Conservation Park, 7.x.1989, *R.J. Bates 21000* (AD 98943259); South-east District: Land being cleared near Mt Boothby, 21.ix.1983, *R.J. Bates 3419* (AD 98407204); South-east District: Yallum, c. 13 km W of Penola, 11.x.1963, *A.C. Beauglehole 18668* (AD 97307025). **VICTORIA**: 6 miles S of Poolaigelo, E side of Dergholm Road, 9.xi.1964, *A.C. Beauglehole 18678* (MEL 221703); Nirranda, c. 20 miles SE of Warrnambool, x.1958, *A.C. Beauglehole 18631* (MEL 221705); Little Desert, Kiata, 9.x.1960, *A.C. Beauglehole 18713* (MEL 221704); 16 km. SSW of Casterton, 16.x.1980, *C. Beardsell s.n.* (MEL 584669); Ararat, x.1932, *?L. Banfield s.n.* (MEL 573513); Ararat, 17.x.1932, *L. Banfield s.n.* (MEL 625353); Ararat, x.1933, *Lang s.n.* (MEL 651011); Gippsland Lakes Coastal Park, 27.x.1983, *A.C. Beauglehole 74B31 & W.R. Beauglehole* (MEL 1531717); Sandringham, xii.1900, *?C. French jun. s.n.* (MEL 573514); Sandringham, x.1900, *C. French jun. s.n. & C. Walter s.n.*(CANB 367952); Near Fyans Lake, N of Pomonal, 12.x.1947, *Robson s.n.* (MEL 1550425); Wilkin, c. 12 miles W of Casterton, 25.x.1961, *C.N. Austin s.n.* (MEL 1532689).

***Distribution and habitat*:** South Australia and Victoria. Grows mostly in coastal heathland, grassland and woodland but extending further inland into similar habitats in the western part of its range. Substrates may be moist or dry sandy soils. Altitude: 0–200 m. (Fig. 2 a)

***Conservation status*:** Widespread but of very sporadic occurrence and apparently in serious decline. Suggest 3E by criteria of Briggs and Leigh (1996) and Endangered (E) by criteria of IUCN (2001).

***Flowering period*:** September to November.

***Pollination biology*:** This species is entomophilous.

***Typification*:** The type sheet contains several fragments, apparently belonging to two individual specimens (A and B), and a single label. The specimens are reasonably well-preserved and are of a single species. This sheet is here designated as the Lectotype. A single flower removed by J.Z. Weber, softened and placed in spirit, has been illustrated as a line drawing. This illustration has been attached to the sheet with the Lectotype.

***Notes*:** *Thelymitra epipactoides* is a very distinctive species, not likely to be confused with any others. It is related to *T. aristata* as suggested by its robust habit, large leaf and bracts, strap-like post-anther lobe and the anther inserted at the base of the column. However, the presence of well-developed auxiliary lobes is unique for the group. An old collection reputed to be from Bulli (New South Wales) has probably been mislabelled.

2. *Thelymitra silena* D.L.Jones, *Orchadian* 12(11): 518 (1999).

Type: Tasmania, Clarke Island, flat at foot of Green Hill, 12 xi. 1998, *J.E. Wapstra ORG1810 & A. Wapstra* (holotype CANB!, isotypes AD!, HO, MEL2089288!).

Illustrations: Jones (1999) page 525; Jones *et al.* (1999) pages 261 & 285; Bates (1999) page 72 (as *Thelymitra* sp. aff. *aristata*); Jones (2006) page 240.

Glabrous terrestrial *herb*, solitary or in small groups. *Tubers* obloid, 1–4 cm long, 6–15 mm wide, fleshy. *Leaf* linear to lanceolate, 10–35 cm long, 9–35 mm wide, erect, canaliculate, thick and fleshy, yellowish-green to green with a purplish base, ribbed abaxially, sheathing at base, apex acute. *Inflorescence* 20–55 cm tall. *Scape* 2.5–10 mm diam., slender to stout, straight, green or purplish. *Sterile bracts* usually 2, linear-lanceolate to lanceolate, 2.5–12 cm long, 5–22 mm wide, closely sheathing, green or purplish, acute to acuminate, apex often uncinate. *Fertile bracts* ovate-acuminate to obovate-acuminate, 8–35 mm long, 4–12 mm wide, closely sheathing the pedicel, green or purplish. *Pedicels* 3–10 mm long, slender. *Ovary* cylindric to narrowly obovoid, 8–14 mm long, 2.5–4 mm wide. *Flowers* 3–15, 23–38 mm across, pale blue, often campanulate, opening tardily in hot weather. *Perianth segments* 10–19 mm long, 6–14 mm wide, concave, often shortly apiculate; *dorsal sepal* obovate to oblanceolate, obtuse to subacute; *lateral sepals* obovate to oblanceolate, slightly asymmetric, subacute; *petals* obovate, obtuse to subacute; *labellum* obovate to oblanceolate, obtuse to acute. *Column* erect from the end of ovary, 7–9 mm long, 4–5.5 mm wide, cream to white; *post-anther lobe* hooding the anther, 2–3 mm long, 1.5–2.2 mm wide, pale brown grading to yellow; *post-anther lobe extension* 2–2.5 mm long, globose, apex deeply bilobed, lobes irregularly toothed, sometimes with a terminal spur, yellow; *auxiliary lobes* absent; *lateral lobes* converging, variable, 0–1 mm long, oblong to triangular or absent, obliquely erect, each with a sparse, terminal, mop-like tuft of white hairs, the individual hairs 0.4–1.1 mm long, or hairs absent. *Anther* inserted c. mid-way along column, ovoid, 2.3–2.8 mm long, 1.5–2.2 mm wide,

warty, connective produced into a short obtuse beak to 0.5 mm long; *pollinarium* 2.1–2.5 mm long; *viscidium* abortive; *pollinia* friable, mealy, white. *Stigma* situated at base of column, ovate-quadrate, c. 2 mm long, c. 3 mm wide, somewhat vestigial, margins irregular. *Capsules* obovoid, 14–20 mm long, 5–12 mm wide, erect, ribbed, slightly pruinose. (Fig. 1 b, Fig. 5 d–f)

***Selected specimens examined*: TASMANIA**: Clarke Island. Lower southern slope of Steep Hill, 1.xi.1982, *J.S. Whinray 5141* (HO 328791 & MEL 2045893); Clarkes Island. East of Maclaines Creek, 31.x.1982, *J.S. Whinray 5079* (MEL 2047683); Clarke Island. Lower southern slope of Steep Hill, 1.xi.1982, *J.S. Whinray 5140* (MEL 2045885); Clarke Island. Near Sandy Lagoon, 12.xi.1979, *J.S. Whinray 2327* (MEL 594275); Clarke Island. Maclaines Bay, 11.xi.1979, *J.S. Whinray 2311* (MEL 594274); Clarke Island, xi.1895, *L. Rodway s.n.* (MEL 1532073); Clarkes Island. Flat south of Sandy Lagoon, 16.xi.1979, *J.S. Whinray 2520* (CAN8 340259); Scamander Coastal Reserve, 31.x.1987, *R.J. Bates s.n.* (AD 98746495); 8icheno, 13.x.1988, *R.J. Bates s.n.* (AD RJ8TAS); Ridgeway Park, Ridgeway, 26.xi.2000, *H. Wapstra JAJ795* (MEL 2087461 & MEL 2089298); Mt Nelson near Hobart, x.1920, *H.M.R. Rupp 425* (NSW 190568); N slope of Mt 8rown, Tasman Peninsula, 21.xi.2003, *A.Gray 1313* (HO).

***Distribution and habitat*:** Apparently endemic to Tasmania where known only from Clarke Island (Furneaux Group) in Bass Strait, Bridport, Scamander, South Bruny Island, Mt Brown on the Tasman Peninsula and Hobart. On Clarke Island it grows in sedgeland dominated by *Gahnia* tussocks with scattered shrubs. Elsewhere it grows in heathy woodland. Soils are sandy or peaty loams. Altitude 10–50 m. (Fig. 2 b)

***Conservation status*:** Of very sporadic occurrence but sometimes locally common and conserved. Suggest 2RC by criteria of Briggs and Leigh (1996) and Rare (R) by criteria of IUCN (2001).

***Flowering period*:** October to November

***Pollination biology*:** The tardily opening flowers, vestigial lateral lobes on the column, abortive viscidium, friable, mealy pollen, vestigial stigma and the high incidence of seed pod development would suggest that this species is probably autogamous.

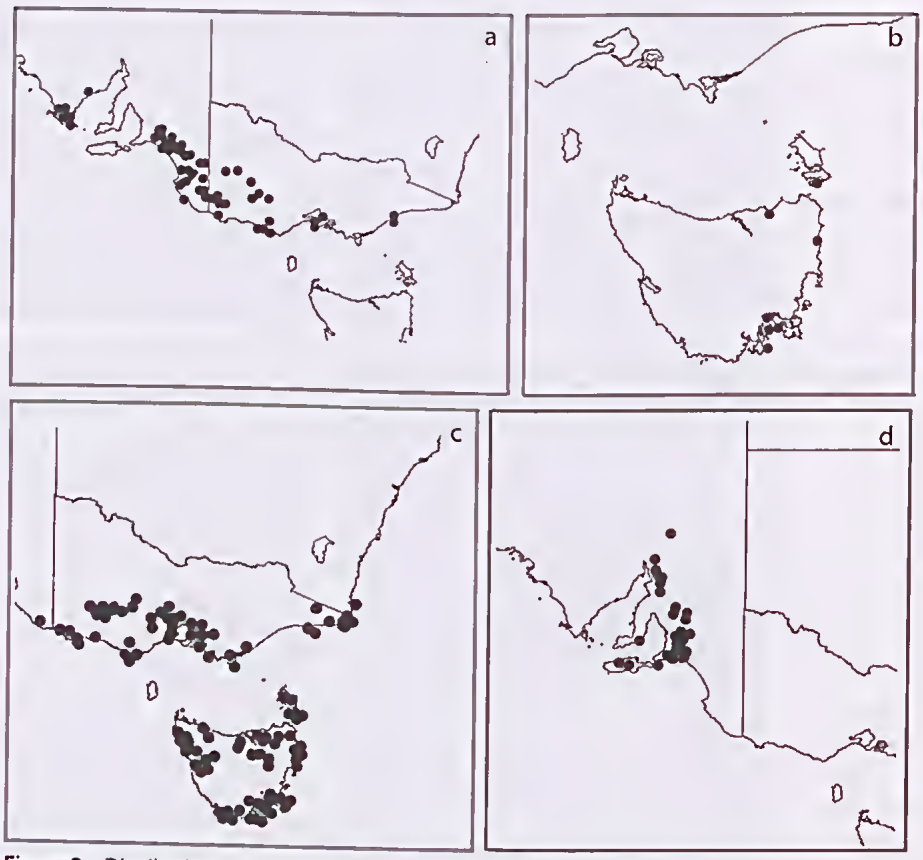

Figure 2a. Distribution of: **a**. *Thelymitra epipactoides*; **b**. *Thelymitra silena*; **c**. *Thelymitra aristata*; **d**. *Thelymitra grandiflora*.

Notes: On Clarke Island, *T. silena* grows sympatrically with *T. aristata* and the two are obviously closely related. The latter can be readily distinguished by its darker blue flowers that open more readily, its more or less flat, strap-like post-anther lobe on the column, longer lateral lobes with many hairs in dense tufts and a more basal anther. The South Australian species *T. grandiflora* is also related to *T. silena*, but the former has darker blue, pale purplish to lilac flowers, a less globose post-anther lobe, longer lateral lobes with many more hairs and a more basal anther.

L. Rodway collected *T. silena* on Clarke Island in late November 1895, and sent a specimen to Baron Ferdinand von Mueller in Melbourne. The specimen was accompanied by the note "The enclosed *Thelymitra* from Clarke Island has a total absence of lateral lobes to the column wing. Otherwise it does not differ from robust forms of *T. aristata* Lind. The short anther and papillose termination to the column wing being exactly in accord. I thought it might interest you. I will endeavour to find out if it is a mere sport next season." At the time of collection the specimen was past anthesis and had splitting seed capsules. By the time the plants flowered again in the following season, Mueller was probably already dead, and there is no evidence that Rodway returned to Clarke Island to collect more specimens as he had intended. The species was apparently not collected again until November 1979, by J.S Whinray.

A collection of this species, housed at AD, reputedly originating from Wilsons Promontory in Victoria is in need of confirmation.

3. *Thelymitra aristata* Lindl., *Gen. Sp. Orch. Pl.* 521 (1840).

Type: Tasmania, Welcome River near Woolnorth, xi. 1837, *R. Gunn 939* (lectotype K!); *Residual syntypes*: Tasmania, Circular Head, xii. 1837, *R. Gunn 941* (BM!,K!,P!).

Thelymitra murdochiae Nicholls, *Victorian Naturalist* 50: 219, t. 35 (1934). *Type:* Victoria, Wonthaggi, 7 xi. 1933, *E.H. Homann s.n.* (holotype MEL651736!, MEL2039622!). (as *T. Murdochae*)

Illustrations: Nicholls (1969) plates 33 & 34 (as *T. grandiflora*); Jones (1988) pages 286, 288 & 289; Bates & Weber (1990) plate 198; Weber & Entwisle (1994) fig. 179 a–c; Backhouse & Jeanes (1995) page 330; Jones *et al.* (1999) pages 260 & 265; Jeanes & Backhouse (2006) page 199; Jones (2006) 239.

Glabrous terrestrial *herb*. *Tubers* ovoid, 1–4 cm long, 5–20 mm wide, fleshy. *Leaf* linear to linear-lanceolate, 10–40 cm long, 5–40 mm wide, erect, canaliculate, fleshy, dark or light green with a purplish base, ribbed abaxially, sheathing at base, apex acute. *Inflorescence* 20–100 cm tall. *Scape* 2–9 mm diam., slender to stout, straight, green or purplish. *Sterile bracts* 1–4, linear to lanceolate, 3–15 cm long, 5–25 mm wide, closely sheathing, dark green with a purplish base, acute, lower ones leaf-like. *Fertile bracts* ovate-acuminate to obovate-acuminate, 7–35 mm long, 3–10 mm wide, closely sheathing the pedicel, green or purplish. *Pedicels* 4–25 mm long, slender. *Ovary* cylindric to narrowly obovoid, 8–20 mm long, 2–5 mm wide. *Flowers* 2–40, 15–45 mm across, usually blue to violet, opening moderately freely in warm weather. *Perianth segments* 10–25 mm long, 4–10 mm wide, concave to almost flat, shortly apiculate; *dorsal sepal* ovate to lanceolate, acute; *lateral sepals* ovate to lanceolate, acute; *petals* ovate to lanceolate, acute; *labellum* ovate to lanceolate, acute, often narrow than other segments. *Column* erect from the end of ovary, 5.5–8 mm long, 2–3.5 mm wide, white, pale blue or greenish; *post-anther lobe* not hooding the anther, 2–3 mm long, 1.5–2.2 mm wide; *post-anther lobe extension* 1.5–2.5 mm long, more or less flat, strap-like, straight or gently curved, apex often shallowly bilobed, lobes toothed or incised, yellow with a dark purplish collar; *auxiliary lobes* absent; *lateral lobes* converging, 1.5–2.5 mm long, digitiform, obliquely erect, each with a more or less terminal short toothbrush-like tuft of white to pale yellow hairs, the individual hairs 1–1.7 mm long. *Anther* inserted at base of column, mostly obscured behind stigma, ovoid to almost spherical, 1.8–2.6 mm long, 1.4–2.2 mm wide, warty, connective produced into an obtuse beak to c. 0.4 mm long; *pollinarium* 1.4–2.2 mm long; *viscidium* circular to reniform, c. 0.5 mm long; *pollinia* coherent, white. *Stigma* situated at base of column, ovate-quadrate, 1.5–2.5 mm long, 1.5–2.5 mm wide, margins irregular. *Capsules* obovoid, 10–20 mm long, 5–6 mm wide, erect, ribbed. (Fig. 1 c, Fig. 5 g–i)

***Selected specimens examined*: SOUTH AUSTRALIA:** South East: Mt Burr, 11.x.1973, *R.J. Bates s.n.* (AD 97722494). **NEW SOUTH WALES:** Roadside near Eden, 4.x.1987, *R.J. Bates 10535*

(AD 98741369). **VICTORIA**: Mornington Peninsula. Stony Point, about 1 km north-west of railway station, 29.x.1971, *T.B. Muir 5036* (MEL 533510); Gippsland. Southern boundary of Marlo Aerodrome, 7 km E of Marlo, 7.x.1973, *T.B. Muir 5170* (MEL 221673); Little Ti-tree Creek, between Cavendish & Victoria Range South, 19.xi.1968, *A.H. Corrick s.n.* (MEL 665158); Pyrete Range, xi.1932, *G. Lyell s.n.* (MEL 573899); Creswick, x.1973, *F. Luke s.n.* (MEL 538347); Ararat, x.1933, *?L. Banfield s.n.* (MEL 573517); Creswick, 11.xi.1928, *J.H. Willis s.n.* (MEL 577250); Blackwood, x.1938, *G. Mayer s.n.* (MEL 650378). **TASMANIA**: Cape Barren Island, Furneaux Group, 5.xi.1973, *J.S. Whinray 56B* (MEL 533327); Flinders Island, Tanners Bay Tinfield, 27.x.1967, *J.S. Whinray s.n.* (MEL 1532017); 1 km W of Glenwood Plants turnoff, 4.xi.1990, *D.L. Jones 6967 & C.H. Broers* (HO 326145); Marsh west of Apsley River, 22.xi.1986, *P. Collier 1892* (HO 119207); North of Southport Lagoon, 6.xii.1989, *P. Collier 4433* (HO 119805); Picketts Plain, 13.xi.1983, *A. Moscal 4019* (HO 101541); Flinders Island, xi.1912, *L. Rodway s.n.* (HO 99330); Rocky Cape, 30.x.1987, *R.J. Bates s.n.* (AD); Cape Barren Island, Furneaux Group, 24.x.1973, *J.S. Whinray 133* (AD 97512292); East Coast, Dianas Basin, 6.xi.1880, *A. Simson RSR4733* (AD 97721295).

***Distribution and habitat*:** Southeastern Australia, but apparently rare in South Australia and New South Wales. Grows in open forest, woodlands, heathy woodlands and heathland on soils ranging from well-drained sand to peaty soils around swamp margins. Altitude: 0–300 m. (Fig. 2 c)

***Conservation status*:** Widespresad, common and well conserved.

***Flowering period*:** September to November

***Pollination biology*:** This species is entomophilous.

***Typification*:** The type sheet contains four specimens with two labels, representing two separate collections. The three specimens on the left have Gunn's number 939, and were collected in November 1837 at Welcome River near Woolnorth in far north-western Tasmania. The single specimen on the right has Gunn's number 941, and was collected in December 1837 at Circular Head, Tasmania. All four specimens are of fairly uniform appearance, and both collections were cited by Lindley in the protologue. The three left hand specimens have been designated as the lectotype by an unknown worker *in sched.*, presumably as this is the larger collection and the first mentioned in the protologue. On the lower part of the sheet, near the three left hand specimens, there is a sketch of a column, apparently executed by Lindley. It is possibly the uncharacteristic appearance of the post-anther lobe of the column in this rather rudimentary sketch that has lead to so much confusion regarding the identity of this species for more than 100 years.

***Lindley's Latin description* (Lindley 1840):** *T. aristata*. T. folio ensiformi canaliculato vaginisque acutissimis, spicâ multiflorâ, bracteis aristatis, cuculli laciniis lateralibus pedicellatis villosis intermediâ emarginatâ glanduloso-serratâ. (*Thelymitra* with leaf sword-like, channelled, and with the sheaths very acute, raceme many-flowered, bracts aristate, the lateral flaps of the hood pedicellate, woolly, column emarginate in the middle, glandular-serrate).

***Notes*:** Plants consistent with Lindley's description and notes on *T. aristata*, and with Gunn's collections 939 and 941 on the type sheet, are common in north-western Tasmania and have been collected recently and studied. This taxon is relatively common and widespread in southeastern Australia. *Thelymitra aristata* is closely related to *T. kangaloonica* but the latter species grows at higher altitude, is generally less robust with a smaller leaf, bracts and flowers. *Thelymitra aristata* is also closely related to *T. grandiflora* from South Australia and *T. silena* from Tasmania, but it differs from both in having generally darker blue flowers and a flatter, more strap-like post-anther lobe on the column. It also differs from *T. silena* in that the lateral lobes of the column are always well developed and have dense tufts of hairs.

Rare hybrids between *T. aristata* and *Thelymitra juncifolia* Lindl. have been collected near Rocky Cape in northern Tasmania, and between *T. aristata* and *T. ixioides* near Genoa in eastern Victoria.

4. *Thelymitra grandiflora* Fitzg., *Gard. Chron.* (new ser.) 17(433): 495 (1882).

***Type*:** Mount Lofty, South Australia, x., *R.D. Fitzgerald s.n.* (lectotype 'A' BM!, *fide* J.Z. Weber 1990 *in sched.*; isolectotypes BM!).

Illustrations: Fitzgerald (1888) 2: 3; Bates & Weber (1990) plate 197 (as *T. aristata*); Jones (2006) page 239.

Glabrous terrestrial *herb*. *Tubers* ovoid, 1–4 cm long, 10–15 mm wide, fleshy. *Leaf* linear to linear-lanceolate, 10–40 cm long, 10–30 mm wide, erect, canaliculate, fleshy, dark green, often glaucous, with a green or purplish base, ribbed abaxially, sheathing at base, apex acute. *Inflorescence* 20–80(–100) cm tall.

Scape 2–8 mm diam., slender to stout, straight, green or purplish, often glaucous. *Sterile bracts* 2–4, linear to lanceolate, 3–15 cm long, 5–25 mm wide, closely sheathing, green or purplish, acute, lower ones leaf-like. *Fertile bracts* ovate-acuminate to obovate-acuminate, 7–35 mm long, 3–10 mm wide, closely sheathing the pedicel, green or purplish. *Pedicels* 4–15 mm long, slender. *Ovary* cylindric to narrowly obovoid, 7–12 mm long, 2–4 mm wide. *Flowers* 2–30, 20–40 mm across, more or less campanulate, usually blue, lilac, mauve or pale purplish, rarely pink, opening moderately freely in warm weather. *Perianth segments* 8–20 mm long, 4–10 mm wide, concave, shortly apiculate; *dorsal sepal* ovate to lanceolate, acute; *lateral sepals* ovate to lanceolate, slightly asymmetric, acute; *petals* ovate to lanceolate, acute; *labellum* ovate to lanceolate, acute, often narrower than other segments. *Column* erect from the end of ovary, 5–7 mm long, 2–3.5 mm wide, lilac, mauve or greenish; *post-anther lobe* not hooding the anther, 2.5–3 mm long, 2–3 mm wide; *post-anther lobe extension* 2–2.5 mm long, strap-like with a thick, fleshy base and often with decurved lateral margins, straight or gently curved, apex often variously bilobed, lobes toothed or incised, yellow with a brownish collar; *auxiliary lobes* absent; *lateral lobes* converging, 1.5–2.5 mm long, digitiform, obliquely erect, each with a terminal toothbrush-like arrangement of white hairs, the individual hairs 1.2–1.5 mm long. *Anther* inserted at base of column, mostly obscured behind stigma, ovoid, 1.8–2.6 mm long, 1.4–2.2 mm wide, warty, connective produced into an obtuse beak c. 0.4 mm long; *pollinarium* 1.5–2.2 mm long; *viscidium* circular to reniform, c. 0.5 mm long; *pollinia* coherent, white. *Stigma* situated at base of column, ovate-quadrate, 1.5–2.5 mm long, 1.5–2.5 mm wide, margins irregular. *Capsules* obovoid, 10–20 mm long, 5–6 mm wide, erect, ribbed. (Fig. 1 d, Fig. 6 a–c)

***Selected specimens examined*: SOUTH AUSTRALIA:** Scotts Creek, Mt Lofty Ranges, 11.xi.1906, *R.S. Rogers s.n.* (MEL 2016025); Bugle Ranges (MEL 1S49710); Flinders Ranges District: Alligator Gorge, Battery Range, 30.ix.19B6, *M.A. Clements 4312* (CANB 8605457); South Lofty District; Bradbury, 29.xii.1980, *M.A. Clements 2265* (CANB B100017); Flinders Range District: Southern Flinders Range, near Alligator Gorge; along main ridge, 14.x.1968, *R. Nash s.n.* (CAN8 8104435); Flinders Ranges District: Alligator Gorge, Battery Range, 30.ix.1986, *M.A. Clements 4312* (CANB 8605457); Lofty South District: S of Cherry Gardens, xi.1954, *R. Nash s.n.* (CANB B104S66); Southern Lofty: Cleland Conservation Park, 24.x.1983, *P. Hornsby 25* (AD 98538261); Southern Lofty: Myponga Conservation Park, 14.x.1986, *D.E. Murphet 223* (AD 9B6S0396); Southern Lofty: Mylor, 30.xii.1976, *R.J. Bates 1151* (AD RJB1151); Flinders Ranges: Alligator Gorge, 27.ix.198B, *R.J. Bates 15531* (AD 9920B02); Yorke Peninsula District: Stansbury, 1B.ix.1976, *R.J. Bates s.n.* (AD RJBYP).

***Distribution and habitat*:** Apparently endemic to South Australia, mostly in the Mount Lofty Ranges and Southern Flinders Ranges, but also recorded for the Yorke Peninsula and Kangaroo Island where possibly now extinct. Grows in open forest and scrubland, particularly in rocky places on hard clay or gravelly soils. Altitude: 5–600 m. (Fig. 2 d)

***Conservation status*:** Reasonably widespread, localised but sometimes locally common and well conserved.

***Flowering period*:** September to December.

***Pollination biology*:** This species is entomophilous.

***Typification*:** The type sheet contains three specimens with two labels, possibly all part of the same collection, but it is impossible to be sure. The specimen on the right (A) is associated with the main label giving the plant name, place of publication of the plant name, collection locality and month of collection. The two specimens on the left (B and C) are associated with a second label in the same hand giving just the plant name. Specimen A has been designated as the Lectotype *in sched.* by J.Z. Weber (1990), and specimens B and C as Isolectotypes. All three specimens are well preserved and are of the same species, specimen A being the most robust plant, but missing a small portion of the scape just below the inflorescence. Specimens B and C are virtually complete.

***Notes*:** *Thelymitra grandiflora* differs from *T. aristata* and *T. kangaloonica* by its often lilac to pale purplish flowers and broader post-anther lobe that is thicker at the base, often has decurved lateral margins and is usually more obviously bilobed and toothed at the apex. *Thelymitra grandiflora* is also closely related to *T. silena* from Tasmania, but the latter has paler flowers, a more globose column post-anther lobe and shorter lateral lobes with fewer hairs.

5. *Thelymitra adorata* Jeanes, *sp. nov.*

Thelymitra aristata Lindl. *affinis anthera ad columnam prope medium affixa sub anthesi a stigma non obscurata, lobo post-antheram ad apicem profunde fisso marginibus lateralibus recurvioribus differt.*

Type: New South Wales. Wadalba, ix. 2001, *B. Branwhite JAJ1030* (holotype MEL *2173020*, isotype CANB).

Illustrations: Bell *et al.* (2005) front cover; Jones (2006) 238.

Glabrous terrestrial *herb. Tubers* not seen. *Leaf* linear to linear-lanceolate, 10–40 cm long, 5–20 mm wide, erect, canaliculate, fleshy, ribbed abaxially, green with a purplish base, sheathing at base, apex acute. *Inflorescence* 20–60 cm tall. *Scape* 2–5 mm diam., slender to stout, straight, green or purplish. *Sterile bracts* 2–4, linear to lanceolate, 2–13 cm long, 5–15 mm wide, closely sheathing, green and purplish, acute, lower ones leaf-like. *Fertile bracts* ovate-acuminate to obovate-acuminate, 6–22 mm long, 3–7 mm wide, closely sheathing the pedicel, green or purplish. *Pedicels* 1–14 mm long, slender. *Ovary* cylindric to narrowly obovoid, 3–12 mm long, 2–3.5 mm wide. *Flowers* 2–13, 15–27 mm across, opening moderately freely in warm weather. *Perianth segments* 8–13 mm long, 4–7 mm wide, often shortly apiculate, deep blue; *dorsal sepal* ovate to ovat-lanceolate, acute; *lateral sepals* ovate to ovate-lanceolate, often slightly asymmetric, acute; *petals* ovate to ovate-lanceolate, acute; *labellum* ovate-lanceolate to lanceolate, acute, often narrower than other segments. *Column* erect from the end of ovary,

Figure 3. a. *Thelymitra adorata*; **b.** *Thelymitra kangaloonica*; **c.** *Thelymitra planicola*. (photographs a. Stephen Bell, Eastcoast Flora Survey; b. Ron Tunstall; c. Jeff Jeanes, RBG Melbourne)

5.5–6.5 mm long, 2.5–3.5 mm wide, white to pale blue; *post-anther lobe* not hooding the anther, 2.5–3.5 mm long, 1.5–2.2 mm wide; *post-anther lobe extension* 1–1.5 mm long, more or less semicylindric, gently curved, dark brownish, apex yellow, distal margin irregularly toothed or incised, incurved, also with a narrow central notch or split 0.5–1 mm deep; *auxiliary lobes* absent; *lateral lobes* converging, 1.5–2 mm long, digitiform, porrect or obliquely erect, curved gently, each with a more or less terminal mop-like tuft of white hairs, the individual hairs 1–1.5 mm long. *Anther* inserted about mid-way along column, base partly obscured behind stigma, ovoid, 2–3 mm long, 1.5–2 mm wide, connective produced into a beak 0.4–0.6 mm long; *pollinarium* 1.5–2.5 mm long; *viscidium* circular to reniform, c. 0.6 mm diam.; *pollinia* white, friable, mealy. *Stigma* situated at base of column, ovate-quadrate, 2–2.5 mm long, 2–2.5 mm wide. *Capsules* obovoid, 10–20 mm long, 5–7 mm wide, erect, ribbed. (Fig. 3 a, Fig. 6 d–f)

***Specimens examined*: NEW SOUTH WALES**: Warnervale, edge of Parters Creek wetland, ix.2001, *B. Branwhite JAJ1033* (MEL 2172988); New South Wales, *B. Branwhite ORG2759* (CANB 611001); Wadalba, 29.ix.1998, *B. Branwhite ORG1571* (CANB 611789.3 *p.p.*)

***Distribution and habitat*:** Apparently confined to the Central Coast (Harden 1993) of New South Wales in the vicinity of Gosford. Grows in grassy woodlands dominated by *Corymbia maculata* (Hook.) K.D. Hill & L.A.S. Johnson (Spotted Gum) with *Themeda triandra* Forssk. (Kangaroo Grass) understorey. Altitude: 10–40 m. (Fig. 4 a).

***Conservation status*:** Known from only a few collections in the Gosford area and apparently extremely rare. All known sites are subject to imminent or eventual housing developments. Other threats include habitat fragmentation, cattle and horse grazing, illegal collection and competition from invasive weeds (Bell *et al.* 2005). Suggest 2E by criteria of Briggs and Leigh (1996) and Endangered (E) by criteria of IUCN (2001).

***Flowering period*:** September and October

***Pollination biology*:** The pollination biology of this species is unknown, however the friable pollen and the very high degree of capsule development would suggest that it is probably autogamous.

***Notes*:** *Thelymitra adorata* is closely related to *T. aristata* but the latter has a flatter, more strap-like post-anther lobe that lacks an obvious apical split and the anther is inserted more or less at the base of the column at anthesis and is mostly obscured behind the stigma. *Thelymitra planicola* is similar to *T. adorata* but the post-anther lobe of the former is more obviously semi-cylindric in shape, is entire to shallowly bilobed but not deeply split at the apex and does not extend as far beyond the point of insertion of the lateral lobes.

The introduced grass *Andropogon virginicus* L. (Whisky Grass) is a threat at one site.

***Etymology*:** Latin *adoro*, to adore, to worship; the column in profile has been likened to a person in prayer.

6. *Thelymitra kangaloonica* Jeanes, *sp. nov.*

Thelymitra aristatae Lindl. *affinis in habitu graciliore, folio angustiore, floribus minoribus dehiscentibus tardioribus in tempu et in habitatione differt.*

***Type*:** New South Wales. Central Tablelands: Tourist Road Swamp, near Robertson, 7 xi. 2001, *D.L. Jones*

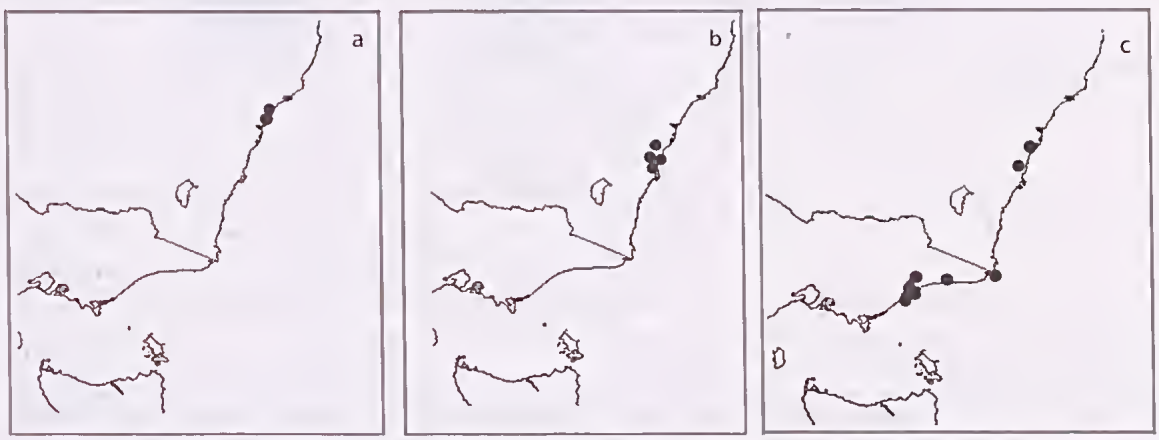

Figure 4. Distributians of: **a**. *Thelymitra adarata*; **b**. *Thelymitra kangalaanica*; **c**. *Thelymitra planicala*

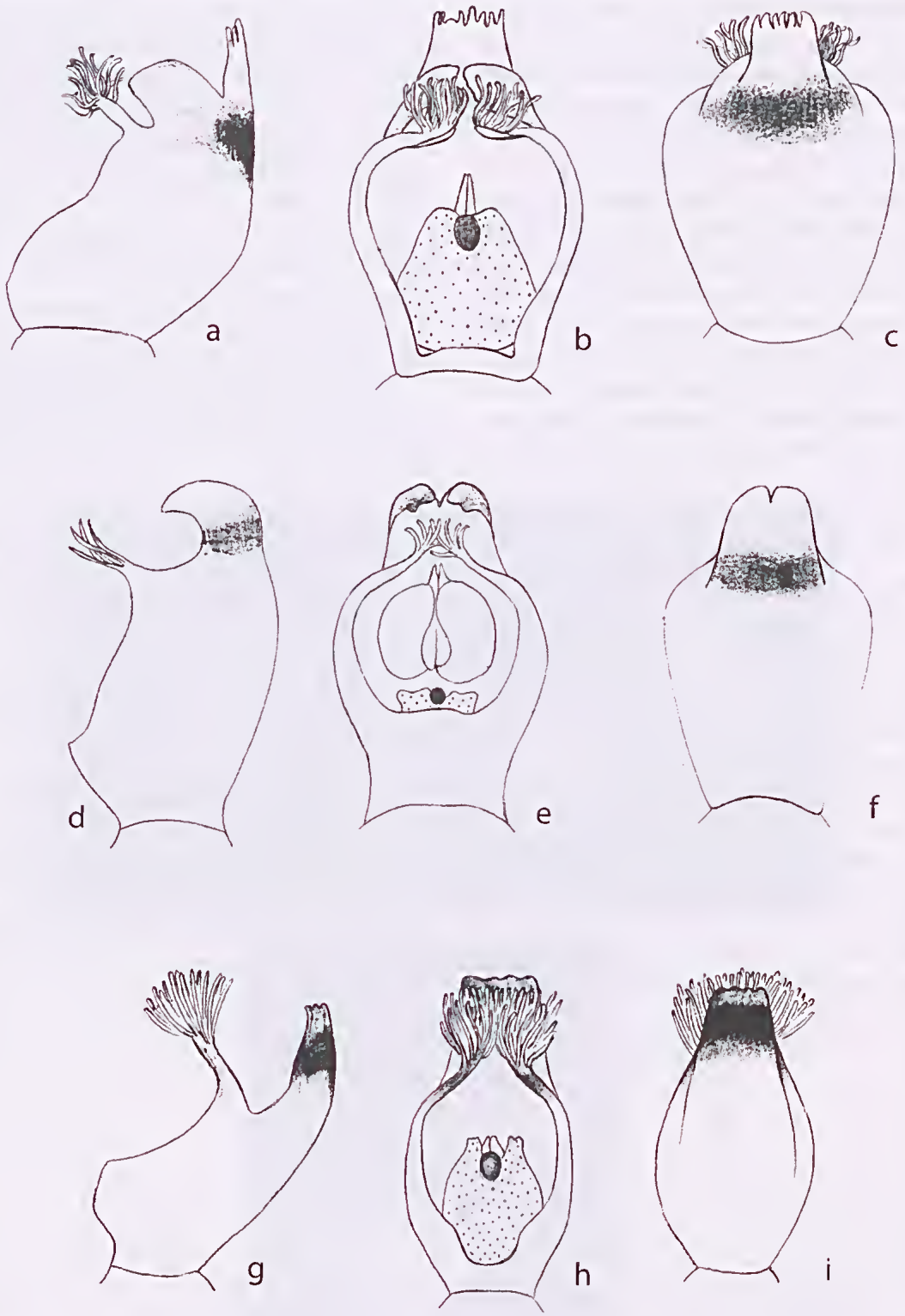

Figure 5. *Thelymitra epipactoides*: **a.** column from side ×6; **b.** column from front ×6; **c.** column from rear ×6. *Thelymitra silena*: **d.** column from side ×6; **e.** column from front ×6; **f.** column from rear ×6. *Thelymitra aristata*: **g.** column from side ×6; **h.** column from front ×6; **i.** column from rear ×6

18108 (holotype CANB 633110; isotypes MEL 2172091, NSW, BRI).

Illustrations: Bishop (2000) plate 59 (as *T. aristata*); Jones (2006) 239.

Glabrous terrestrial *herb*. *Tubers* not seen. *Leaf* linear to linear-lanceolate, 10–35 cm long, 5–20 mm wide, erect, canaliculate, fleshy, green with a purplish base, ribbed abaxially, sheathing at base, apex acute. *Inflorescence* 20–56 cm tall. *Scape* 1.5–3.5 mm diam., straight, green or purplish. *Sterile bracts* usually 3, occasionally 2, linear to lanceolate, 1.5–11 cm long, 3–14 mm wide, green to purplish, lower ones closely sheathing and sometimes leaf-like, upper one usually only half encircling the scape and mostly free, acute to acuminate. *Fertile bracts* ovate-acuminate to obovate-acuminate, 6–20 mm long, 3–6 mm wide, closely sheathing the pedicel, green or purplish. *Pedicels* 2–10 mm long, slender. *Ovary* cylindric to narrowly obovoid, 6–11 mm long, 1.5–3 mm wide. *Flowers* 2–15, 15–32 mm across, dark blue with darker longitudinal veins, opening moderately freely in warm weather. *Perianth segments* 8–18 mm long, 4–8 mm wide, concave, shortly apiculate; *dorsal sepal* ovate, obtuse to subacute; *lateral sepals* ovate to lanceolate, slightly asymmetric, acute; *petals* ovate, obtuse to subacute; *labellum* ovate to lanceolate, acute, slightly smaller than other segments. *Column* erect from the end of ovary, 5.5–6.5 mm long, 2.5–3.5 mm wide, white to mauve; *post-anther lobe* not hooding the anther, 2–2.5 mm long, 1.5–2 mm wide; *post-anther lobe extension* 1.5–2 mm long, more or less flat, strap-like, gently curved, yellow with a dark purplish collar, apex decurved, often shallowly bilobed, lobes toothed or incised; *auxiliary lobes* absent; *lateral lobes* converging, 1.5–2.3 mm long, digitiform, obliquely erect, each with a more or less terminal short toothbrush-like tuft of white hairs, the individual hairs 1–1.6 mm long. *Anther* inserted at base of column, mostly obscured behind stigma, ovoid to almost spherical, 2–2.5 mm long, 1.7–2.2 mm wide, warty, connective produced into an obtuse beak to c. 0.3 mm long; *pollinarium* 1.7–2.2 mm long; *viscidium* circular to transverse-elliptic, 0.5–0.6 mm long, 0.6–0.8 mm wide; *pollinia* friable, mealy, white. *Stigma* situated at base of column, ovate-quadrate, 1.6–2 mm long, 1.8–2 mm wide, margins irregular, hardly bilobed at apex. *Capsules* obovoid, 8–12 mm long, 4–6 mm wide, erect, ribbed. (Fig. 3 b, Fig. 6 g–i)

***Specimens examined*: NEW SOUTH WALES**: Central Coast: East Kangaloon, Molly Morgan Swamp, 9.xi.1969, *B. Whitehead 2350, 2348, 2349, 2306* (CAN8 8104568, CAN8 8104431, CAN8 8104432 & CAN8 8104433); Central Coast: East Kangaloon, 16.xi.1970, *B. Whitehead 2437* (CAN8 8104567); NE of East Kangaloon, 9.xi.1969, *B. Whitehead s.n.* (NSW 88618); Central Coast: Tourist Road, E of Bowral, 22.xi.1998, *M.A. Clements 9805* (CAN8 611740); Central Tablelands: Fitzroy Falls, 15.xi.1992, *A.D. Bishop J245/7-12* (NSW 430838); Central Coast: Robertson, swamp near Tourist Road, 22.x.1986, *R.G. Tunstall 174* (CAN8 8605737).

***Distribution and habitat*:** Apparently endemic to the Central Tablelands (Harden 1993) of New South Wales, in the Fitzroy Falls/Robertson/Kangaloon area. Grows in seasonally swampy sedgeland on grey silty clay loam. Altitude: 600–700 m. (Fig. 4 b)

***Conservation status*:** Locally common, but with a very restricted range and probably endangered. Drying of its swampy habitat by a proposed borefield appears to be the main immediate threat facing this species. Suggest 2E by criteria of Briggs and Leigh (1996) and Endangered (E) by criteria of IUCN (2001).

***Flowering period*:** Late October and November

***Pollination biology*:** The friable, mealy pollen and the high degree of capsule development would suggest that this species is facultatively autogamous. The moderately large, freely opening flowers with a strong spicy fragrance and the functional viscidium indicate that this species is at least sometimes capable of entomophily.

***Notes*:** *Thelymitra kangaloonica* is closely related to *T. aristata*, but the latter grows in lower altitude heathlands and heathy woodlands, is a generally more robust species often with a larger leaf, larger sterile and fertile bracts, longer pedicels and larger flowers that generally appear earlier in the season.

***Etymology*:** From the township of Kangaloon in the Central Tablelands (Harden 1993) district of New South Wales. The type collection and most other preserved specimens came from this general area.

7. *Thelymitra planicola* Jeanes, *Muelleria* 14: 94 (2000).

Type: Victoria. Golden Beach. SE edge of Lake Reeve, c. 200 m NE of causeway and adjacent to rare plant reserve, 26 x. 1999, *J.A. Jeanes 608* (holotype spirit MEL2069957!, isotypes MEL2069958!, CANB!).

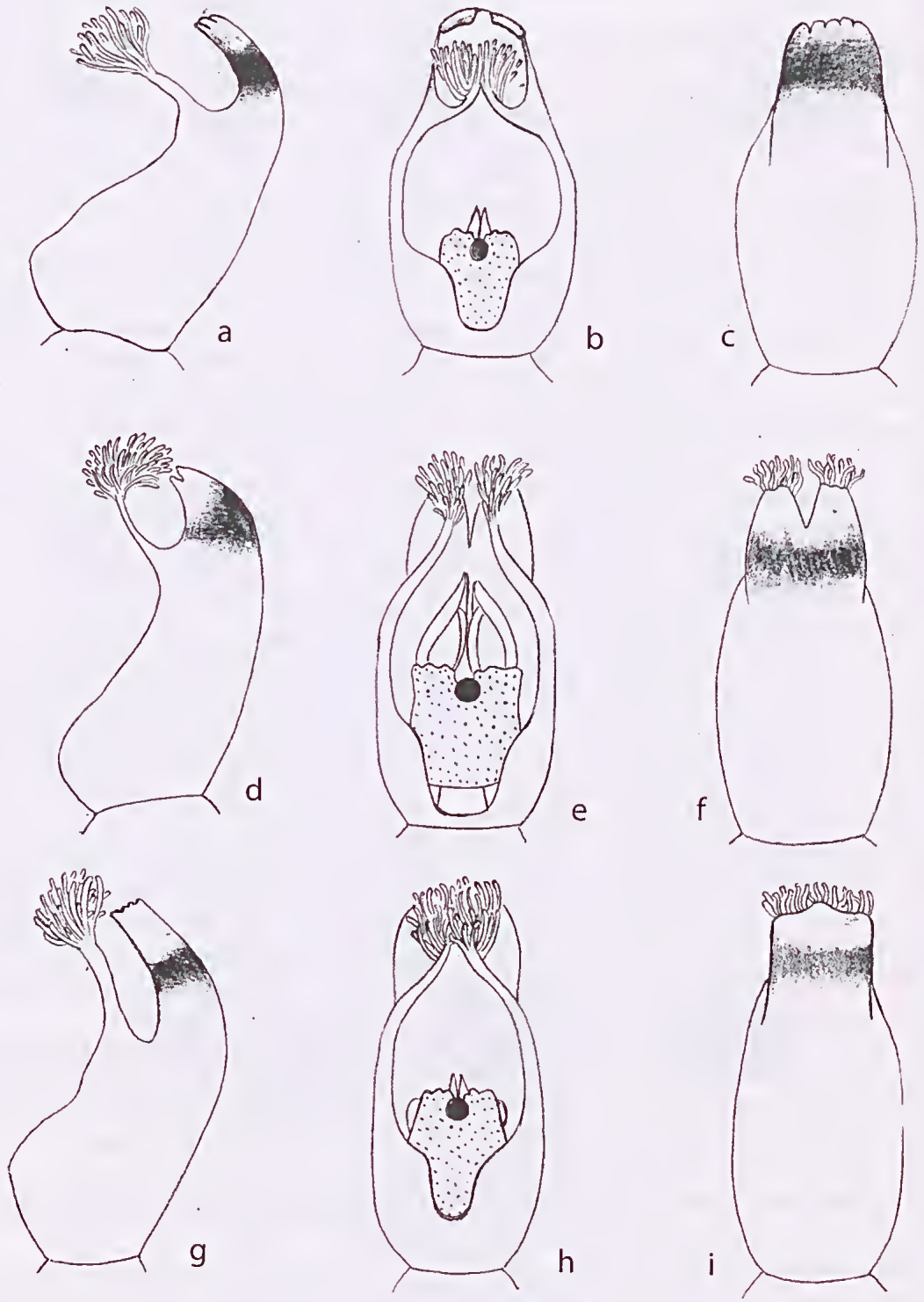

Figure 6. *Thelymitra grandiflora*: **a.** column from side ×8; **b.** column from front ×8; **c.** column from rear ×8. *Thelymitra adorata*: **d.** column from side ×8; **e.** column from front ×8; **f.** column from rear ×8. *Thelymitra kangaloonica*: **g.** column from side ×8; **h.** column from front ×8; **i.** column from rear ×8

Illustrations: Jeanes (2000) fig. 1 e,f,g & h; fig. 5; Jeanes (2004) fig. 6 a,b & c; fig. 28; Jeanes & Backhouse (2006) page 206.

Glabrous, somewhat glaucous terrestrial *herb*. *Tubers* not seen. *Leaf* linear to linear-lanceolate, 10–30 cm long, 5–20 mm wide, erect, leathery, canaliculate, dark green with a purplish base, ribbed abaxially, sheathing at base, apex acute. *Inflorescence* 22–45 cm tall. *Scape* 2–5 mm diam., straight, purplish. *Sterile bracts* 2–4, linear to lanceolate, 2–8 cm long, 5–15 mm wide, green or purplish, lower ones often leaf-like, closely sheathing for most of their length, acute to acuminate. *Fertile bracts* ovate-acuminate to obovate-acuminate, 10–20 mm long, 4–8 mm wide, sheathing the pedicels green or purplish. *Pedicels* 1–8 mm long, stout. *Ovary* cylindric to narrow-obovoid, 3–12 mm long, 1.5–4 mm wide. *Flowers* 2–12, (15–)20–25(–30) mm across, medium blue with darker blue longitudinal veins, opening readily only on hot days. *Perianth segments* (7–)10–13(–15) mm long, 4–8 mm wide, concave, often shortly apiculate; *dorsal sepal* ovate to obovate, obtuse to subacute; *lateral sepals* ovate-lanceolate, slightly asymmetric, acute; *petals* ovate to obovate, obtuse to subacute; *labellum* oblanceolate to obovate, acute, often slightly smaller than other segments. *Column* erect from the end of ovary, 5–6 mm long, 3–4 mm wide, white to pale blue; *post-anther lobe* hooding the anther, 1.5–2 mm long, 1.5–2 mm wide; *post-anther lobe extension* 0.5–1.2 mm long, semi-cylindric, gently curved, mostly dark blackish brown with a thin blue collar, apex shallowly bilobed, yellow, lobes shallowly and irregularly toothed; *auxiliary lobes* absent; *lateral lobes* converging, 1.2–2 mm long, digitiform to somewhat flattened, obliquely erect, curved, each with a short, terminal, mop-like arrangement of white hairs, the individual hairs 0.9–1.5 mm long. *Anther* inserted about mid-way along column, basal part obscured behind stigma, ovoid, 2.7–4 mm long, 1.5–2.2 mm wide, connective produced into a beak c. 0.5 mm long; *pollinarium* 1.5–2.2 mm long; *viscidium* circular, c. 0.5 mm diam.; *pollinia* friable, mealy, white. *Stigma* situated at base of column, more or less quadrate, 2–2.5 mm long, 2–2.5 mm wide, margins irregular. *Capsules* obovoid, 10–16 mm long, 3.5–7 mm wide, erect, ribbed. (Fig. 3 c, Fig. 7 a–c)

***Specimens examined*: NEW SOUTH WALES**: Cultivated CANB ex Orient Point, E of Nowra, 4.xi.1988, *D.L. Jones 3422* (CANB 8807085); Narrabeen, suburb of Sydney, 1.x.1954, *A.W. Dockrill & B.B. Lowry 815* (AD 97631544); Kurnell, Botany Bay N.P., 25.ix.2005, *D. Rouse 25/9a* (MEL 2296310); Kurnell, Botany Bay N.P., 14.ix.2006, *D. Rouse 14/9a* (MEL 2296486). **VICTORIA**: Gippsland Lakes Reserve, 27.x.1984, *A.C. Beauglehole 78814 & J.R. Turner* (MEL 669448); Providence Ponds Flora and Fauna Reserve, 22.x.1984, *A.C. Beauglehole 78729* (MEL 670413); Golden Beach, SE edge of Lake Reeve, 4.xi.1996, *J.A. Jeanes 258* (MEL 2034950); Rail Reserve WSW of Lindenow South, 27.x.1999, *J. Turner JAJ633* (MEL 2069954); Bairnsdale, 24.x.1987, *R.J. Bates 11393* (CANB 478099 specimen 2); Marlo Airport, 15.xi.1987, *R.J. Bates 12172* (AD 98753040); Howe Flat beside walking track to beach, 9.xi.2004, *J.A. Jeanes 1443* (MEL 2265086, MEL 2265086); E side of Mallacoota Inlet, c. 5 km ENE

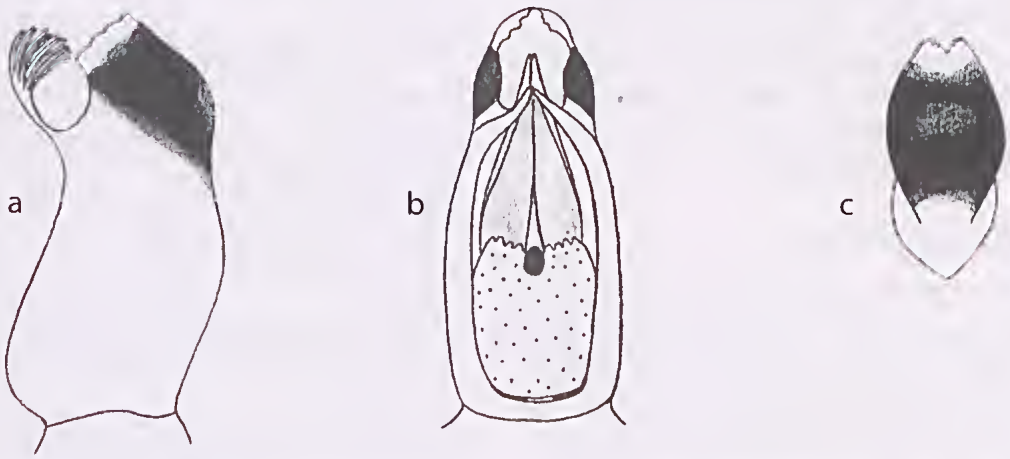

Figure 7. *Thelymitra planicola*: **a.** column from side ×8; **b.** column from front ×8; **c.** column from rear ×8

af Mallacoota near the S end *af* Hawe Flat *faat* track, S.xi.2003, *J. Eichler 194* (MEL 2224848, MEL 2219607).

***Distribution and habitat*:** Eastern Victoria and the New South Wales Central Coast (Harden 1993). Most collections are from the eastern section of the Gippsland Plain Natural Region (Conn 1993), between Sale and Bairnsdale, Victoria, with disjunct collections from near Marlo and Mallacoota and from New South Wales, east of Nowra and near Sydney. Grows in herb-rich grassland and grassy woodland and heathland on soils ranging from sandy loams to clay loams and also around swamp margins. Altitude: 0–80 m. (Fig. 4 c)

***Conservation status*:** Known from only about ten colonies and very few plants. Suggest 3EC by criteria of Briggs and Leigh (1996) and Endangered (E) by criteria of IUCN (2001).

***Flowering period*:** Late October to early November.

***Pollination biology*:** The friable, mealy pollen and the high degree of capsule development would suggest that this species is facultatively autogamous.

***Notes*:** The structure of the post-anther lobe of *T. planicola* is somewhat intermediate between that of *T. aristata* and of members of the *T. pauciflora* complex. This led to some early speculation about the possible hybrid origins of *T. planicola* (Jeanes 2000), but this appears unlikely as it favours a different habitat to that of *T. aristata* and the two have never been found growing sympatrically. In the past (Jeanes 2000, Jeanes 2004) I have treated *T. planicola* tentatively as a member of the *T. pauciflora* complex, but with its moderately tall habit, large fleshy leaf and the large leaf-like lower sterile bracts it would appear to fit more readily in the *T. aristata* complex. Also, the structure of the post-anther lobe extension is not typical of members of the *T. pauciflora* complex, but is rather like some members of the *T. aristata* complex, particularly the recently discovered *T. adorata* from New South Wales.

Acknowledgments

I am grateful to the Australian Biological Resources Study (ABRS) and the Australian Orchid Foundation (AOF) for their financial support of my work on *Thelymitra* during 2000, 2001 and 2002. I wish to thank Bob Bates (AD), Stephen Bell, Boris Branwhite, Mark Clements (CSIRO), John Eichler, David Jones, Dean Rouse and Denis Wilson for supplying me with locality information, conservation status data, specimens or photographs. My colleague Neville Walsh (MEL) kindly wrote the Latin diagnoses and made helpful comments on the text. Many thanks to Enid Mayfield (MEL) for the line drawings. Teresa Lebel (MEL) helped with the intricacies of Photoshop. Thanks also to the directors and curatorial staff at AD, BM, BRI, CANB, E, HO, MEL, NSW, P, PERTH, QRS, SUNIV and WELT for access to specimens.

References

Backhouse, G.N. and Jeanes, J.A. (1995). *The Orchids af Victario*. Melbourne University Press: Carlton.

Bates, R.J. (1999). Self Pallinated Sun Orchids of the *Thelymitra pouciflora – T. longifolia* Alliance in Australia. *The Orchadian* **13**, 65–72.

Bates, R.J. and Weber, J.Z. (1990). *Orchids af Sauth Australio*. Gavernment Printer: South Australia.

Bell, S., Branwhite, B. and Driscoll, C. (2005). *Thelymitra adarata* Jeanes ms (Orchidaceae): papulatian size and habitat of a highly restricted terrestrial orchid from the Central Coast af New Sauth Wales. *The Orchodion* **15**, 6–10.

Bentham, G. (1873). *Floro Austroliensis*, vol. 6. L. Reeve & Ca.: Landon.

Bishop, A. (2000). *Field Guide to the Orchids af New Sauth Woles ond Victorio* 2nd edition. University af New Sauth Wales Press: Sydney.

Black, J.M. (1943). *Floro of South Austrolio* 2nd edition, part 1, Gavernment Printer: Adelaide

Briggs, J.D. and Leigh, J.H. (1996). *Rore or Threotened Australian Plants* (revised edn). CSIRO and Australian Nature Canservation Agency: Canberra.

Clements, M.A. (1989). Catalague af Australian Orchidaceae, *Australian Orchid Reseorch* **1**, 1–160.

Conn, B.J. (1993). 'Natural Regians and Vegetatian of Victoria', in D.B.Foreman and N.G.Walsh (eds), *Flaro of Victoria* 1, 79–158. Inkata Press: Melbourne.

Ewart, A.J. (1931). *Floro of Victorio*. Gavernment Printer: Melbourne.

Fitzgerald, R.D. (1882). New Australian Orchids. *Gardeners' Chranicle* (new series) **17**, 494–495.

Fitzgerald, R.D. (1888). *Austrolion Orchids* val. 2. Gavernment Printer: Sydney.

George, A.S. (1971). A check list of the Orchidaceae af Western Australia. *Nuytsio* **1**, 166–196.

Harden, G.J. (1993). *Floro af New South Wales* val. 4. New South Wales University Press: Kensington

Hooker, J.D. (1858). *Floro Tosmonioe*, vol. 2. Lovell Reeve: Covent Garden.

IUCN (2001). *2001 IUCN Red List Categories ond Criterio*, version 3.1. International Union for Conservation of Nature. Gland: Switzerland.

Jeanes, J.A. (2000). Twa new species of *Thelymitro* (Orchidaceae) from southeastern Australia. *Muellerio* **14**, 91–97.

Jeanes, J.A. (2004). A revisian af the *Thelymitro pauciflara* R.Br. (Orchidaceae) complex in Australia. *Muelleria* **19**, 19–79.

Jeanes, J.A. and Backhause, G.N. (2006). *Wild Orchids af Victaria, Australia*. Aquatic Phatagraphics: Seafard.

Janes, D.L. (1988). *Native Orchids af Australia*. Reed Baaks: Frenchs Farest.

Janes, D.L. (1999). Nates an Tasmanian Orchidaceae including the description af two new species af *Thelymitra* J.R. & G. Farst. *The Orchadian* **12**, 518–519.

Janes, D.L. (2006). *Native Orchids af Australia*. Reed New Halland: Sydney.

Janes, D.L., Wapstra, H., Tanelli, P. and Harris, S. (1999). *The Orchids af Tasmania*. Melbaurne University Press: Carltan.

Lindley, J. (1840). *The Genera and Species af Orchidaceaus Plants*. Ridgways: Landan.

Mueller, F. (1866). *Fragmenta Phytagraphiae Australiae* val. 5. Gavernment Printer: Melbaurne.

Mueller, F. (1882). *Systematic Census af Australian Plants*. M'Carran, Bird & Ca.: Melbaurne.

Mueller, F. (1886). *Key ta the System af Victarian Plants* part 1. Gavernment Printer: Melbaurne.

Nichalls, W.H. (1934). A New Species af the Genus *Thelymitra*, Farst. *Victarian Naturalist* **50**, 218–219.

Nichalls, W.H. (1969). *Orchids af Australia*, the camplete editian (eds D.L. Janes and T.B. Muir). Thamas Nelsan: Melbaurne.

Weber, J.Z. and Entwisle, T.J. (1994). '*Thelymitra*', in N.G.Walsh & T.J.Entwisle (eds), *Flara af Victaria* 2, 840–854. Inkata Press: Melbaurne.

Willis, J.H. (1962). *A Handbaak ta Plants in Victaria*, val. 1. Melbaurne University Press: Parkville.

The functional significance for the orchid *Caladenia tentaculata* of genetic and geographic variation in the mycorrhizal fungus *Sebacina vermifera* s. lat. complex

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Abstract

To investigate the influence of provenance of mycorrhizal fungi on functional diversity in orchids, six isolates of two taxa in the *Sebacina vermifera* complex, were sourced from Victorian *Caladenia tentaculata* populations. Germination of orchid seeds with isolates from their own and other populations in vitro and utilisation of a range of carbon and nitrogen substrates for growth in culture were tested. There was considerable inter- and intra-taxon variation in seed germination abilities but no evidence of a 'home site' advantage for fungal isolates. All isolates utilised the carbon compounds carboxymethyl cellulose and pectin, and inorganic nitrogen in the form of NH_4+ but not NO_3-, as their sole nitrogen source. However, the two fungal taxa differed in ability to utilise sucrose as a sole carbon source. Implications for sourcing mycorrhizal fungi to propagate orchid plants for conservation purposes are discussed.

Keywords: orchid mycorrhiza; seed germination; nutrient utilisation

Muelleria 29(2): 130-140 (2011)

Introduction

Orchid seeds require colonisation by mycorrhizal fungi for germination (Zettler 1997) and depend on this interaction for nutrition into adulthood (Cameron *et al.* 2006, 2007; Girlanda *et al.* 2006). The dependence of orchids on fungi often results in highly dispersed populations and, as a result, these plants face heightened extinction risks (Rasmussen & Rasmussen 2009). Species of the summer dormant terrestrial genus *Caladenia* represent an astounding 5% of Australia's threatened flora (Dixon & Hopper 2009), thus presenting a significant conservation challenge. The ability of orchid mycorrhizal fungi to induce orchid seed germination has been harnessed to propagate plants (symbiotic propagation) for *ex situ* collections and reintroduction into natural habitats (Scade *et al.* 2006; Brundrett 2007; Wright *et al.* 2009). Many critically endangered Victorian orchid species have been reduced to small fragmented populations (Backhouse & Cameron 2005). Thus fungal provenance is a potentially important factor when sourcing mycorrhizal isolates for symbiotic propagation; but one that is currently overlooked.

The majority of mycorrhizal fungi isolated from photosynthetic orchids belong to the anamorphic form genus *Rhizoctonia* (Rasmussen 2002). The *Rhizoctonia* fungi associated with orchids represent an assemblage of taxonomically diverse fungal groups whose teleomorphic (sexual) stages belong to three distantly related basidiomyceteous lineages in the Sebacinales (Sebacinaceae) and Cantharellales (Tulasnellaceae and Ceratobasidiaceae) (Taylor *et al.* 2003; Weiß *et al.* 2004; Taylor & McCormick 2008). *Caladenia* have highly specific mycorrhizal interactions with fungi from the *Sebacina vermifera* complex (Weiß *et al.* 2004; Dearnaley *et al.* 2009; Wright *et al.* 2010; Swarts *et al.* 2010). Members of the Sebacinales are not exclusive in their interactions with orchid plants and are found

to undertake a variety of other ecosystem roles, such as saprotrophs (Roberts 1999), bryophyte endophytes (Newsham & Bridge 2009) and ectomycorrhizas (McKendrick *et al.* 2000; Selosse *et al.* 2002). Despite the ecological importance of these fungi and the varied interactions they form with plants, there are no baseline studies on their nutritional requirements.

In a mycorrhizal symbiosis the fungus transfers soil-derived nutrients to the plant host (Smith & Read 1997). Many Australian soils are nutrient-poor (Attiwill & Leper 1987; Schmit & Steward 1997) and most of the macronutrients essential for plant growth are associated with the organic fraction (King & Buckney 2002), thus ability to access nutrients in organic forms makes mycorrhizal fungi in these soils of significant benefit to their hosts. Orchid mycorrhizal interactions differ from those found in the majority of plant families, as the fungi provide carbon (Cameron *et al.* 2006; Girlanda *et al.* 2006), as well as nitrogen (and phosphorus) to their plant partners (Cameron *et al.* 2007, 2008). While the ability to germinate orchid seed is an essential functional attribute when selecting mycorrhizal fungi for conservation purposes, it is also important to consider their ability to harness different sources of nutrients that can be made available for orchid growth.

The objective of this study was to investigate the influence of fungal provenance on the functional diversity of orchid mycorrhizal fungi from the *Sebacina vermifera* complex. This was achieved by 1) confirming the identity of isolates associating with six geographically distinct *Caladenia tentaculata* study populations growing in a range of vegetation types, edaphic and climatic conditions using ribosomal DNA (rDNA) sequencing, 2) assessing the ability of these isolates to induce *in vitro* germination of orchid seeds from each of the study populations and, 3) comparing their abilities to utilise a range of carbon and nitrogen sources for growth in axenic culture.

Figure 1. A map showing the relative locations of the six Victorian *Caladenia* populations selected for this study.

Materials and Methods

Study populations

Six geographically distinct *Caladenia tentaculata* populations in Victoria, Australia were selected to represent a range of vegetation types and climatic conditions (Table 1). The six study populations (Fig. 1) were located near Maldon (144.06°E, -36.99°S), Chewton (144.27°E, -37.07°S), Eltham (145.14°E, -37.72°S), Inverleigh (144.05°E, -38.03°S), Anglesea (144.18°E, -38.41°S) and Wonthaggi (145.58°E, -38.68°S).

To investigate edaphic conditions present at each site, twenty 10 cm deep soil core samples were taken at 1 m intervals along 20 m transects at each site adjacent to the largest concentration of *C. tentaculata* plants. The soil samples were dried at 40 °C and sent to the State Chemistry Laboratory (Department of Primary Industry, Werribee) for testing. The samples were mixed to make

Table 1. Site characteristics for each *C. tentaculata* population, including Ecological Vegetation Class (EVC), maximum air temperature, mean annual rainfall and mean soil nutrient content of the composite sample from twenty 10 cm soil cores.

Population	EVC	Max air temp. Jan/Jul (°C)	Rainfall (mm/yr)	Total C (%w/w)	Total N (%w/w)	N as NH_4+ (mg/kg)	N as NO_3- (mg/kg)	pH
Anglesea	Heathy forest	23.0/12.6	814	3.8	0.12	4.4	0.9	5.2
Chewton	Box ironbark forest	27.9/11.7	597	2.9	0.12	2.9	3.7	4.8
Eltham	Grassy dry forest	25.1/11.4	748	6.2	0.32	7.2	1.0	4.8
Inverleigh	Grassy woodland	24.4/10.9	562	1.4	0.06	2.3	0.5	5.2
Maldon	Grassy dry forest	28.2/11.3	621	2.8	0.15	8.1	7.4	5.7
Wonthaggi	Coastal heathland	28.2/13.5	945	7.9	0.38	5.6	2.0	5.4

Table 2. The isolate name, accession number (R8GM living collection), GenBank number for ITS sequence and information on the closest Genbank match for the six isolates.

Population	Isolate name	RBGM accession	GenBank accession	Identity (percentage match) of the closest match against GenBank ITS sequences. Numbers in parentheses are the base pairs matching/base pairs compared
Anglesea	A2	080313	EF470248	98% (506/512) DQ983815 *Sebacina vermifera*
Chewton	C3	080314	EF470249	98% (506/512) DQ983815 *S. vermifera*
Eltham	E2	080315	EU526279	97% (407/419) DQ983815 *S. vermifera*
Inverleigh	I4	061048	EU526280	97% (433/446) DQ983815 *S. vermifera*
Maldon	M4	080316	EU526281	96% (410/424) DQ983816 *S. vermifera*
Wonthaggi	W2	080313	EU526282	98% (512/518) DQ983815 *S. vermifera*

a single composite soil sample (w/w) and were tested for pH, total carbon (% w/w), total nitrogen (% w/w), amount of nitrogen as NH_4^+ (mg/kg) and amount of nitrogen as NO_3^-(mg/kg).

Mycorrhizal isolates

Six fungal isolates (Table 2) were obtained, one from each of the six study *C. tentaculata* populations (Fig. 1). Isolates were cultured from stem-collars after removal from the plants using the peloton rinsing method of Rasmussen[9] *et al.* (1990). Isolates were cultured, stored under sterile water and lodged in the Royal Botanic Gardens Melbourne (RBGM) Living Collection as described by Wright *et al.* (2010). Isolate accession numbers are shown in Table 2.

DNA isolation, amplification and sequencing

Fungal mycelia from each of the isolates (Table 2) were grown for 4-6 weeks in low carbon and nitrogen Melin Norkrans liquid media (low CN MMN; Marx & Bryan 1975). The mycelium was then removed, blotted dry, weighed and then crushed to a powder in a mortar and pestle using liquid nitrogen. Qiagen® DNeasy mini kits were used to isolate DNA from each sample according to the manufacturer's instructions. The ITS region of the DNA was amplified using the primer set ITS1- ITS4 (White *et al.* 1990). The PCR reactions and thermal cycling conditions followed those outlined in Wright *et al.* (2010). PCR products were then purified using a Qiagen® PCR purification kit according to the manufacturer's instructions to prepare for ITS sequencing. Purified PCR products were sequenced following the methods outlined in Wright *et al.* (2010).

Sequence analysis

The ITS sequences were edited manually by checking nucleotides against the corresponding chromatographs for sequencer reading errors. The edited ITS sequences were then BLAST searched on GenBank to find the closest matches. Relationships among the *Caladenia* mycorrhizal fungi were investigated by aligning ITS sequences (416 bp) with closely matched sequences downloaded from GenBank, using *Geastrum saccatum* as the out-group. Alignments were constructed using Clustal X and edited manually in MEGA version 4 (Tamura *et al.* 2007). The evolutionary history was inferred using the Maximum Parsimony (MP) method (Eck & Dayhoff 1996) in MEGA. A bootstrap consensus tree was inferred from 10,000 replicates. The MP tree was obtained using the Close-Neighbour-Interchange algorithm with search level 3 (Nei & Kumar 2000) in which the initial trees were obtained with the random addition of sequences (10 replicates). All positions containing gaps and missing data were eliminated from the datasets.

In vitro symbiotic seed germination

Seeds from multiple *Caladenia tentaculata* plants from each of the six populations were surface sterilised (3 minutes in 0.5% NaOCl and rinsed six times in deionised water). They were then placed on individual filter paper wedges in each replicate Petri dish (Bonnardeaux *et al.* 2007), which contained 2.5% oatmeal agar (containing 2.5g crushed rolled oats, 0.1g yeast extract and 10g of agar in 1L of deionised water, pH 5-6, modified from Clements & Elyard 1979). Each Petri dish was inoculated with a single isolate from one of the six populations (Table 2), with a treatment left

uninoculated as a negative control. This process was replicated ten times. The Petri dishes were arranged in a randomised complete block design and exposed to continuous light with a photosynthetic photon flux of 8.3 $\mu mol\ m^{-2}s^{-1}$ at 21°C.

Statistical analysis: *in vitro* seed germination

Germination data were recorded as the number of stage 3 and stage 4 protocorms (Ramsey & Dixon 2003) on each piece of filter paper as a proportion of the initial seed number (the number of seeds without embryos subtracted from the total number of seeds on each piece of filter paper). The mean initial seed number (± standard error of the mean) was 51.3 ± 2.9. The data were analysed using a generalised linear model with binomial errors in GenStat®. A separate statistical analysis was performed on the seed germination data for each individual seed batch.

Carbon and nitrogen utilisation

The six fungal isolates (Table 2) were grown with four different carbon and three different nitrogen sources (described below) as well as in the absence of both carbon and nitrogen in liquid low CN MMN (Marx & Bryan 1975). Thirty mL of each medium was aliquoted into 120mL tissue culture tubes, which were inoculated with a single $5mm^3$ cube of agar excised from the growing edge of colonies of the fungal isolates on agar plates. There were six replicates of each isolate for each medium. A control without fungal inoculation was included for all media (also replicated six times). The tubes were incubated, unagitated, at 21°C. For both the carbon and nitrogen experiments, the positions of the culture tubes from each treatment (media × isolate) were randomly assigned in six blocks. After six weeks the fungal mycelium was separated from the liquid medium by filtration through pre-weighed pieces of filter paper (Sartorium®, Grade 603N) and dried at 65°C for one week. The dry weight of the mycelium from each tube was measured. The mean dry weight for the control was subtracted from the dry weight data for the corresponding medium to correct for any interference due to the weight of residual media on the filter paper (especially particulate matter present in the media containing chitin).

Media modifications

The pH of the low CN MMN was adjusted to 5.0-6.0 before the addition of the ferric EDTA and autoclaved at 121°C for 20 minutes. The four carbon sources used were glucose (Sigma®), sucrose (Sigma®), carboxymethyl cellulose (sodium salt, Sigma®) and pectin (from apple, Sigma®), each to a final concentration of $2gL^{-1}$ (as in Midgley *et al.* 2006). The carbon source was excluded for the negative control.

The three nitrogen sources were nitrate ($NaNO_3$), ammonium ($(NH_4)_2HPO_4$), and chitin (powdered from crab shells, Sigma®), each to a final concentration of $53mgL^{-1}$. The nitrogen source was excluded for the negative control. In the nitrogen comparison, the amount of glucose was adjusted so that each medium had a C:N ratio of 39:1 (as in Midgley *et al.* 2004). Two chitin media were used; Chitin 1 included the carbon content of the chitin in the C:N ratio and Chitin 2 did not.

Statistical analysis: carbon and nitrogen utilisation

Corrected dry weight data were analysed using a general analysis of variance in GenStat®, with media and isolates as factors, and the block fitted as a random factor. The plot of residuals versus fitted values was checked visually for homogeneity of variance and no transformation of the data was required. The significance of the difference between pairs of means was assessed using the least significant difference (l.s.d). As the ability of the isolates to utilise each of the carbon and nitrogen sources individually was also of interest, the analysis described above was also conducted for each isolate's biomass on the range of carbon and nitrogen media separately (with medium as a single factor).

Results

Edaphic conditions

All the soils were acidic (Table 1) and were well below the optimal horticultural level for nitrate (41-60mg/kg, Pivot Ltd 2007). All soils, except that from Chewton, had more nitrogen as ammonium (NH_4^+) than as nitrate (NO_3^-). The soil from Inverleigh was below the optimal total carbon (>1.85%) recommended for horticultural crops (Pivot Ltd 2007).

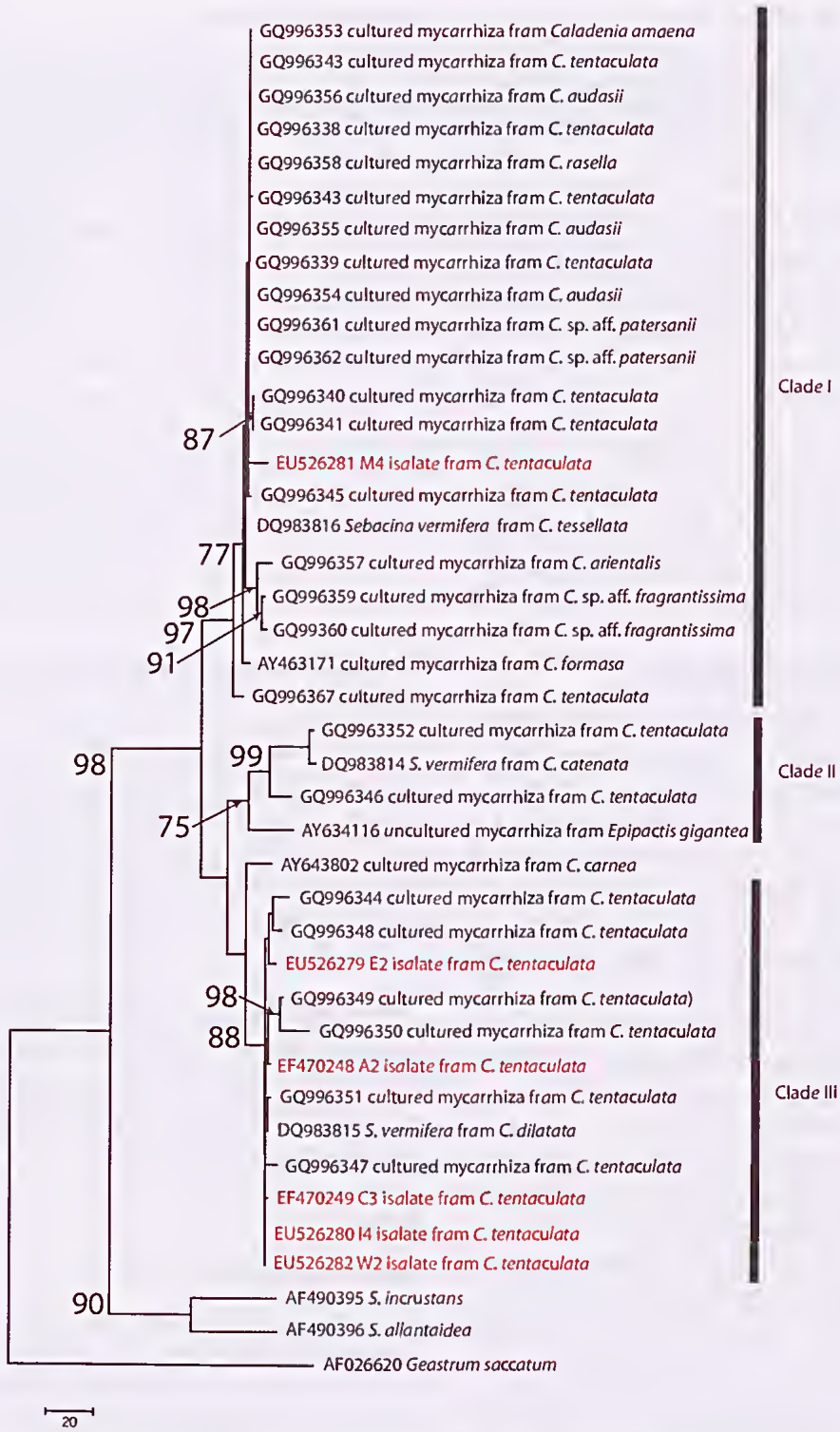
GQ996353 cultured mycarrhiza fram Caladenia amaena
GQ996343 cultured mycarrhiza fram C. tentaculata
GQ996356 cultured mycarrhiza fram C. audasii
GQ996338 cultured mycarrhiza fram C. tentaculata
GQ996358 cultured mycarrhiza fram C. rasella
GQ996343 cultured mycarrhiza fram C. tentaculata
GQ996355 cultured mycarrhiza fram C. audasii
GQ996339 cultured mycarrhiza fram C. tentaculata
GQ996354 cultured mycarrhiza fram C. audasii
GQ996361 cultured mycarrhiza fram C. sp. aff. patersanii
GQ996362 cultured mycarrhiza fram C. sp. aff. patersanii
GQ996340 cultured mycarrhiza fram C. tentaculata
GQ996341 cultured mycarrhiza fram C. tentaculata
87
EU526281 M4 isalate fram C. tentaculata
GQ996345 cultured mycarrhiza fram C. tentaculata
DQ983816 Sebacina vermifera fram C. tessellata
77
GQ996357 cultured mycarrhiza fram C. arientalis
98
GQ996359 cultured mycarrhiza fram C. sp. aff. fragrantissima
97
GQ99360 cultured mycarrhiza fram C. sp. aff. fragrantissima
91
AY463171 cultured mycarrhiza fram C. formasa
GQ996367 cultured mycarrhiza fram C. tentaculata
Clade I
GQ9963352 cultured mycarrhiza fram C. tentaculata
98
99
DQ983814 S. vermifera fram C. catenata
GQ996346 cultured mycarrhiza fram C. tentaculata
75
AY634116 uncultured mycarrhiza fram Epipactis gigantea
Clade II
AY643802 cultured mycarrhiza fram C. carnea
GQ996344 cultured mycarrhiza fram C. tentaculata
GQ996348 cultured mycarrhiza fram C. tentaculata
EU526279 E2 isalate fram C. tentaculata
98
GQ996349 cultured mycarrhiza fram C. tentaculata)
88
GQ996350 cultured mycarrhiza fram C. tentaculata
EF470248 A2 isalate fram C. tentaculata
GQ996351 cultured mycarrhiza fram C. tentaculata
DQ983815 S. vermifera fram C. dilatata
GQ996347 cultured mycarrhiza fram C. tentaculata
EF470249 C3 isalate fram C. tentaculata
EU526280 I4 isalate fram C. tentaculata
EU526282 W2 isalate fram C. tentaculata
Clade III
90
AF490395 S. incrustans
AF490396 S. allantaidea
AF026620 Geastrum saccatum
20

Figure 2. Maximum parsimony analysis of ITS sequences of a range of mycorrhizal fungi from *Caladenia* and other terrestrial orchids (red font = isolates from current study). Branches corresponding to partitions reproduced in less than 50% bootstrap replicates are collapsed. The bootstrap values represent percentages of 10,000 replicates. Only bootstrap values of 70 or over are displayed.

Isolate identification

The ITS sequences from isolates A2, C3, E2, I4 and W2 were 97-99% similar to DQ983815, a *S. vermifera* isolate from *Caladenia dilatata* R.Br originally obtained by J.H. Warcup but M4 was a 96% match to DQ983816, a *S. vermifera* isolate from *C. tessellata*, also originally isolated by J.H. Warcup (Deshmukh *et al.*, 2006; Table 2). The ITS alignments contained a total of 359 positions in the final dataset, of which 125 were parsimony informative. The six isolates from this study fell within two well-supported clades previously described by Wright *et al.* (2010). MP analysis of these sequences revealed that the majority fell within clade III (88% bootstrap support), along with DQ983815, whereas M4 belonged to clade I (97% bootstrap support) as did DQ983816 (Fig. 2).

In vitro symbiotic seed germination

The mycorrhizal status of the six isolates was confirmed with positive seed germination recorded for each. All germination percentages were relatively low, with none exceeding 50%. Differences were observed in the specificity of the six isolates. M4 was the only isolate to germinate *Caladenia* seeds from all six populations. Four isolates (A2, C3, E2 and I4) failed to germinate seed from the Maldon population and another isolate (W2) produced only 2.4% germination of seed from this population (Table 3). There were also significant differences among germination percentages induced by the six isolates in relation to seeds from the Anglesea, Chewton and Eltham populations ($P<0.05$, Table 3). The general trend was that inoculation with the A2, E2 and I4 isolates gave significantly higher germination than the C3, M4 and W2 isolates. None of the isolates gave significantly higher germination of seeds from their own population when compared to isolates from other populations. C3 gave significantly lower germination percentages from Chewton seeds and W2 failed to germinate seeds from its own Wonthaggi population.

Carbon source utilisation

The effects of the different carbon sources on the mycelium dry weights were significantly different ($P<0.001$, Table 4). The dry weight of the isolates was significantly greater when grown in the glucose, pectin and carboxymethyl cellulose media in comparison to the sucrose medium and the medium lacking a carbon source. The effect of isolate was not significant ($P>0.05$) and there was no significant interaction between carbon source and isolate ($P>0.05$). Only isolate M4 produced significantly greater mycelium (dry weight) in the sucrose medium than the zero carbon control (l.s.d=17.4, $P>0.05$).

Nitrogen source utilisation

The different nitrogen sources had a significant effect on the mycelium dry weights ($P<0.001$, Table

Table 3. Mean percentage seed germination (stage 3 plus stage 4) ± standard error of the mean for seed from all six populations inoculated with fungi from all six populations at 16 weeks. The same letters indicate transformed means that are not significantly different within a single column ($p<0.05$).

Seed / Isolate	Anglesea	Chewton	Eltham	Inverleigh	Wonthaggi	Maldon
Anglesea (A2, Clade III)	45.7 ± 18.9^{b}	52.3 ± 14.1^{b}	41.8 ± 12.6^{b}	42.2 ± 12.6^{a}	12.5 ± 12.5^{a}	0
Chewton (C3, Clade III)	17.3 ± 7.0^{a}	5.7 ± 2.6^{a}	20.5 ± 10.2^{ab}	29.7 ± 13.4^{a}	6.3 ± 4.8^{a}	0
Eltham (E2, Clade III)	46.3 ± 6.5^{b}	2 8.8 ± 5.1^{b}	27.4 ± 9.1^{ab}	33.4 ± 7.5^{a}	11.5 ± 6.6^{a}	0
Inverleigh (I4, Clade III)	36.7 ± 7.0^{b}	33.4 ± 7.6^{b}	34.4 ± 8.2^{b}	44.2 ± 9.5^{a}	5.6 ± 5.6^{a}	0
Wonthaggi (W2, Clade III)	2.4 ± 12.6^{ab}	24.1 ± 12.5^{ab}	7.3 ± 6.3^{ab}	7.7 ± 3.8^{a}	0	2.4 ± 1.2^{a}
Maldon (M4, Clade I)	5.4 ± 3.2^{a}	8.6 ± 4.5^{ab}	4.9 ± 2.8^{a}	15.8 ± 5.6^{a}	29.8 ± 20.6^{a}	15.6 ± 6.6^{a}
No fungi	0	0	0	0	0	0

Table 4. Mean dry weight of mycelium (mg) ± the standard error of the mean of the six fungal isolates growing in low CN MMN liquid media with a variety of carbon sources.

Isolate / Carbon source	A2 Clade III	C3 Clade III	E2 Clade III	I4 Clade III	W2 Clade III	M4 Clade I	Mean for carbon source l.s.d = 6.3
Glucose	18.9 ± 5.0	18.3 ± 4.7	18.6 ± 4.2	17.6 ± 4.9	20.6 ± 3.0	20.6 ± 4.1	19.1
Sucrose	8.3 ± 2.9	10.3 ± 1.3	3.0 ± 1.4	5.1 ± 3.6	3.9 ± 2.6	20.3 ± 5.5	8.4
Cellulose	19.0 ± 3.6	27.3 ± 8.7	18.8 ± 8.1	19.5 ± 8.0	11.2 ± 5.2	26.2 ± 4.1	20.3
Pectin	18.8 ± 6.0	13.7 ± 2.3	21.7 ± 3.6	11.5 ± 6.0	18.3 ± 5.0	18.0 ± 5.1	17.0
No Carbon	0.0 ± 0.0	3.0 ± 3.4	0.0 ± 0.0	1.1 ± 1.1	4.2 ± 2.7	0.0 ± 0.0	1.4
Mean for isolate l.s.d = 6.9	13.0	14.5	12.4	11.0	11.7	17.0	

5). The mean for ammonium was the highest and was significantly greater than all other nitrogen sources and the medium lacking nitrogen. There was no significant difference between the mean for nitrate and that for the no nitrogen control. The mean for the Chitin 2 medium was also significantly greater than the no nitrogen control, nitrate and the Chitin 1 medium. There was no significant effect of isolate or a significant interaction between nitrogen source and isolate were significant ($P>0.05$).

Discussion

There was both genetic and functional diversity among the six *Caladenia tentaculata* isolates, revealing that fungal provenance is an important consideration when selecting isolates for symbiotic propagation for conservation. The isolates belonged to two different taxa within the *Sebacina vermifera* complex, and differed both in their effectiveness to germinate orchid seeds and their specificity for seeds from different *Caladenia* populations. While there was little variation in ability to utilise different carbon and nitrogen sources, there was strong evidence that these fungi can act as saprotrophs and utilise forms of inorganic nitrogen available to them in Australian orchid habitats. To our knowledge, the results of this study provide the first baseline data on the nutrient requirements of fungi from the Sebacinales.

Genetic diversity of *Caladenia* isolates

The mycorrhizal isolates were closely related, but belonged to two different ITS clades (Fig. 2), with isolate M4 falling in clade I and the other five isolates falling in clade III as defined by Wright *et al.* (2010). The three clades defined by Wright *et al.* (2010) contained members of the *Sebacina vermifera* complex as circumscribed by Weiß *et al.* (2004). Species and generic concepts within this complex are uncertain (Warcup 1988; Weiß *et al.* 2004; Wright *et al.* 2010); however, analysis of percentage sequence similarity between the three ITS clades suggested that they are separate at least

Table 5. Mean dry weight of mycelium (mg) ± the standard error of the mean of the six fungal isolates growing in low CN MMN liquid media with a variety of nitrogen sources.

Isolate / Nitrogen source	A2 Clade III	C3 Clade III	E2 Clade III	I4 Clade III	W2 Clade III	M4 Clade I	Mean for nitrogen source l.s.d = 4.4
NO_3	5.0 ± 2.1	4.6 ± 1.1	5.8 ± 3.8	7.6 ± 3.0	9.0 ± 2.9	6.1 ±2.5	7.0
NH_4	22.5 ± 3.3	13.7 ± 2.1	25.2 ± 3.8	22.5 ± 3.1	24.7 ± 3.9	26.3 ± 3.5	22.5
Chitin 1	5.8 ± 2.0	6.8 ± 12.9	10.4 ± 3.9	5.8 ± 3.7	8.2 ± 3.9	4.9 ± 2.6	6.7
Chitin 2	16.3 ± 8.1	20.3 ± 8.1	10.8 ± 3.1	14.3 ± 3.7	14.2 ± 3.9	10.3 ± 2.6	14.4
No Nitrogen	10.1 ± 3.9	8.3 ± 2.0	10.1 ± 4.0	4.3 ± 2.5	4.9 ± 2.6	4.7 ± 2.1	7.0
Mean for isolate l.s.d = 4.9	11.9	10.7	12.5	10.9	12.2	10.5	

at the species level, with the mean divergence of clade I isolates at 1.7% and that of clade III at 3.8% (Wright *et al.* 2010). Both the well-supported clades identified in the MP analysis contained ITS sequences from a number of other *Caladenia* fungi, corroborating all previous studies, which have found that *Caladenia* species have highly specific mycorrhizal associations with a narrow range of closely related fungi (Warcup 1988; Dearnaley *et al.* 2009; Huynh *et al.* 2009; Swarts *et al.* 2010; Wright *et al.* 2010).

Effect of provenance on *in vitro* symbiotic seed germination

Variation in seed germination effectiveness was observed both within and between the two taxa from the *Sebacina vermifera* complex identified in this study (Table 3). The most striking difference was the lack of germination ability of most clade III isolates with seed from the Maldon population from which the clade I isolate originated. Interestingly, differences were also observed in the specificity of the clade III isolates for seeds from other populations from which the same taxon had been isolated. Similar variation has been observed in the seed germination effectiveness of mycorrhizal isolates from single fungal taxa (as defined by ITS sequence analysis) in *Tulasnella-Chiloglottis* (Roche *et al.* 2010) and other *Sebacina-Caladenia* (Huynh *et al.* 2009) associations, suggesting that either individual orchid fungal taxa contain genetically different strains that differ in mycorrhizal fitness, or ITS sequence divergence is not adequate for defining orchid fungal species. The 3.8% divergence found by Wright *et al.* (2010) among clade III isolates is a little higher than the 3% cut off widely accepted for species level taxa on ITS data (*e.g.* Tedersoo *et al.* 2009) and it is possible that more than one taxon is present within clade III. For some fungal groups it is also becoming apparent that the ITS region may not be adequate for delimiting species (Nilsson *et al.* 2008; Stefani *et al.* 2009) and regions such as actin, β-tubulin, elongation factor 1-α, and ribosomal polymerase B genes give finer resolution and clearer definition of species limits (*e.g.* Bruns & Shefferson 2004; Damm *et al.* 2009). The functional variation observed in this and other orchid mycorrhizal studies suggests that investigation of fungal species limits using a range of gene regions is required.

The results of this study revealed that while *C. tentaculata* fungi differed in their seed germination effectiveness and specificity there was no evidence of "home site" advantage. These results indicate that the use of fungal isolates from the same provenance as seeds in symbiotic propagation of orchids is not necessary when producing large seedling numbers for conservation purposes. Furthermore, genetic studies indicate that there is often a range of fungi present in individual *Caladenia* populations (Wright *et al.* 2010), and therefore it is likely that fungi from a single population will also exhibit a range of seed germination effectiveness and specificity.

Effect of provenance on utilisation of different carbon and nitrogen sources

There was no variation in the ability of the six isolates to utilise the different carbon and nitrogen sources when all isolates and media combinations were analysed as a factorial (Tables 4 and 5), suggesting that these fungi are very similar with respect to their carbon and nitrogen nutrition. There was, however, considerable evidence that these fungi are able to utilise forms of carbon and nitrogen available to them in orchid habitats.

All six isolates were able to utilise the complex cell-wall-related carbohydrates (carboxymethyl cellulose and pectin, Table 4), indicating the production of some cellulolytic and pectinolytic enzymes. The production of cell wall degrading enzymes suggests that the fungi tested could act as saprotrophs. As cellulose and, to a lesser degree, pectin constitute a large proportion of the organic carbon in leaf litter and soil available to fungi (Kögel-Knabner 2002), these results indicate that *Caladenia* isolates with the ability to germinate seed *in vitro* have the capacity to contribute to the carbon nutrition of orchid plants.

There was very little variation among isolates in their ability to utilise the majority of carbon sources. However, the M4 isolate (the sole representative of *Sebacina vermifera* clade I) was the only isolate capable of growth with sucrose as a sole carbon source, indicating some inter-taxon variation in carbon utilisation. While this result is difficult to interpret on an ecological level, as simple sugars such as sucrose are not considered part of the organic soil fraction (Kögel-Knabner 2002), it does indicate a degree of metabolic variation among members of the *Sebacina vermifera* complex.

It was clear that all six isolates showed a distinct preference for ammonium as an inorganic source of nitrogen and were not able to utilise nitrate (Table 5). The preference for one inorganic nitrogen source over another varies between different forms of mycorrhizal fungi, with studies showing that ammonium is the main inorganic nitrogen source utilised by ectomycorrhizal fungi (France & Reid 1984; Anderson *et al.* 1999; Sawyer *et al.* 2003), whereas ericoid mycorrhizal fungi can utilise both ammonium and nitrate (Chen *et al.* 1999; Midgley *et al.* 2004). The mycorrhizal fungi of some Northern Hemisphere terrestrial orchids have been shown to utilise ammonium and/or nitrate as sources of nitrogen (Stephen & Fung 1971), whereas others are unable to utilise either of these two nitrogen sources (Hadley & Ong 1978). As ammonium is the most abundant form of inorganic nitrogen in most Australian soils (Attiwill & Leeper 1987; Schmit & Steward 1997) including five of the six study sites investigated in this study (Table 1) the capacity of mycorrhizal isolates to utilise this form of inorganic nitrogen would greatly benefit their associated orchids.

All isolates were able to utilise chitin, the organic form of nitrogen used in this study, when the chitinous carbon was not considered in the C:N ratio (Chitin 2 medium). This is the first time that the capacity of orchid mycorrhizal fungi to utilise chitinous nitrogen as its sole nitrogen source has been demonstrated. It remains to be seen if *Sebacina vermifera*-like fungi are able to utilise other organic forms of nitrogen. Organic nitrogen can represent a significant proportion of the nitrogen in Australian soils (Schmidt & Stewart 1997; King & Buckley 2002). Chitin is the main component of fungal cell walls and it has been suggested that senescent fungal hyphae within soil may provide a significant source of nitrogen for mycorrhizal fungi (Kerley & Read 1997).

Mycorrhizal fungi play a significant role in nitrogen acquisition for the orchid species *Goodyera repens* R.Br. (Cameron *et al.* 2006). It is likely that the mycorrhizal fungi of *Caladenia* species also provide nitrogen to their associated orchids. Their capacity to utilise the most prevalent form of inorganic nitrogen in Australian soils, as well as forms of organic nitrogen indicates that they are able to absorb nitrogen present in soils that is not readily available to their orchid associates. It is clear that *Caladenia* mycorrhizal isolates with the ability to germinate seed *in vitro* have the capacity to contribute to the nitrogen nutrition of adult plants.

Conclusions

The genetic identity and functional attributes of the orchid mycorrhizal fungi differed among the six provenances investigated in this study. While there was considerable inter- and intra-taxon variation in seed germination effectiveness and specificity there was no evidence of "home site" advantage, suggesting that fungi from different provenances can be used for successful symbiotic propagation. The similarity in their growth on different carbon and nitrogen sources, suggests that provenance does not influence the ability of these fungi to access these important soil carbon and nitrogen nutrients and therefore their capacity to contribute to the nutrition of their associated orchids. Given that there are at least three species-level taxa in the *Sebacina vermifera* complex that associate with *Caladenia* in Australia, it will be instructive to investigate seed germination effectiveness and specificity in a wider sample of this genetic variation across a number of populations. Testing a wider variety of carbon substrates across more isolates may also reveal more substantial functional variation among the fungal taxa.

Acknowledgments

We would like to acknowledge the technical assistance of Tina Gilbertson. We also acknowledge the generous funding of the Australian Orchid Foundation, the Department of Sustainability and Environment and The Natural Heritage Trust.

References

Anderson, I.C., Chambers, S.M. and Cairney, J.W.G. (1999). Intra- and inter-specific variation in patterns of organic and inorganic nitrogen utilisation by three Australian *Pisolithus* species. *Mycological Research* **103**, 1579-1587.

Attiwill, P.M. and Leeper, G.W. (1987). *Forest Soils and Nutrient Cycles*. Melbourne University Press, Carlton, Australia.

Backhouse, G. and Cameron, D. (2005). Application of IUCN 2001 Red List categories in determining the conservation status of native orchids of Victoria, Australia. *Selbyana* **26**, 58-74.

Bonnardeaux Y., Brundrett M., Batty A., Dixon K., Koch J., Sivasithamparam K. (2007). Diversity of mycorrhizal fungi of terrestrial orchids: compatibility webs, brief encounters, lasting relationships and alien invasions. *Mycological Research* **111**, 51-61.

Brundrett, M. (2007). Scientific approaches to Australian temperate terrestrial orchid conservation. *Austrolion Journal of Botany* **55**, 293-307.

Bruns, T.D. and Shefferson, R.P. (2004). Evolutionary studies of ectomycorrhizal fungi: recent advances and future directions. *Conodion Journol of Botany* **82**, 1122-1132.

Cameron, D.D., Leake, J.R. and Read, D.J. (2006). Mutualistic mycorrhiza in orchids: evidence from plant-fungus carbon and nitrogen transfers in the green-leaved terrestrial orchid *Goodyero repens*. *New Phytologist* **171**, 40S-416.

Cameron, D.D., Johnson, I., Leake, J.R. and Read D.J. (2007). Acquisition of Inorganic Phosphorus by the Green-leaved Terrestrial Orchid *Goodyera repens* *Annols of Botony* 99, 831-834.

Chen, A., Chambers, S.M. and Cairney, J.W.G. (1999). Utilisation of organic nitrogen and phosphorus sources by mycorrhizal endophytes of *Woollsia pungens* (Cav.) F.Muell. (Epacridaceae). *Mycorrhiza* **8**, 181-187.

Clements, M.A. and Ellyard R.K. (1979). The Symbiotic Germination of Australian Terrestrial Orchids. *Americon Orchid Society Bulletin* 48, 810-815.

Damm, U., Woudenberg, J.H.C., Cannon, P.F., and Crous, P.W. (2009). *Colletotrichum* species with curved conidia from herbaceous hosts. *Fungal Diversity* **39**, 45-87.

Dearnaley, J.D.W. Murray A.J. and Mathieson M.T. (2009). Molecular identification of a mycorrhizal Sebacinaeae from the endangered *Coladenia atroclavia* (black clubbed spider orchid). *Austrolosion Mycologist* **28**, 45-49.

Deshmukh, S., Huckelhoven, R., Schafer, P., Imani, J., Sharma, M., Weiß, M., Waller, F. and Kogel, K.H. (2006). The root endophytic fungus *Piriformospora indica* requires host cell. *Proceedings of the Nationol Acodemy of Science* **103**, 18450-18457.

Dixon, K.W. and Hopper, S.D. (2009). An introduction to *Calodenia* R.Br. - Australasia's jewel among terrestrial orchids. *Austrolion Journal of Botony* **57**, i-vii.

Eck R.V. and Dayhoff M.O. (1966). *Atlos of Protein Sequence ond Structure*. National Biomedical Research Foundation, Silver Springs, Maryland.

France, R.C. and Reid, C.P.P. (1984). Pure growth of ectomycorrhizal fungi on inorganic nitrogen sources. *Microbial Ecology* **10**, 187-195.

Girlanda, M., Selosse, M.A., Cafasso, D., Brilli, F., Delfine, S., Fabbian, R., Ghignone, S., Pinelli, P., Segreto, R., Loreto, F., Cozzolino, S. and Perotto, S. (2006). Inefficient photosynthesis in the Mediterranean orchid *Limodorum abortivum*: Are mycorrhiza always mutualisms? *Molecular Ecology* **15**, 491-504.

Hadley, G. and Ong, S.H. (1978). Nutritional requirements of orchid endophtyes. *New Phytologist* **81**, 561-569.

Huynh, T.T., Thomson, R., McLean, C.B. and Lawrie A.C. (2009). Functional and genetic diversity of mycorrhizal fungi from single plants of *Caladenia formosa* (Orchidaceae). *Annols of Botony* **104**, 757-765

Kerley, S.J. and Read, D.J. (1997). The biology of mycorrhiza in the Ericaceae. *New Phytologist* **136**, 691-701.

King, S.A. and Buckney, R.T. (2002). Invasion of exotic plants in nutrient-enriched urban bushland. *Austrol Ecology* **27**, 573-583.

Kögel-Knabner, I. (2002). Macromolecular organic composition of plant and microbial residues as inputs to soil organic matter. *Soil Biology ond Biochemistry* **34**, 139-162.

Marx, D.H. and Bryan, W.C. (1975). Growth and ectomycorrhizal development of loblolly pine seedlings in fumigated soil infested with the fungal symbiont *Pisolithus tinctorius*. *Forest Science* **21**, 245-254.

Midgley, D.J., Chambers, S.M. and Cairney, J.W.G. (2004). Inorganic and organic substrates as sources of nitrogen and phosphorus for multiple genotypes of two ericoid mycorrhizal fungal taxa from *Woollsia pungens* and *Leucopogon parviflorus* (Ericaceae). *Austrolion Journol of Botany* **52**, 63-71.

Midgley, D.J., Jordan, L.A., Saleeba, J.A. and McGee, P.A. (2006). Utilisation of carbon substrates by orchid and ericoid mycorrhizal fungi from Australian dry sclerophyll forests. *Mycorrhiza* **16**, 175-182.

Nei, M. and Kumar S. (2000). *Moleculor evolution and phylogenetics*. Oxford University Press, New York

Nilsson, R.H., Kristiansson E., Ryberg M., Hallenberg N. and Larsson K.H. (2009). Intraspecific ITS variability in the kingdom fungi as expressed in the international sequence databases and its implications for molecular species identification. *Evolutionary Bioinformotics* **4**, 193-201.

Ramsey, M. and Dixon, K. (2003). 'Propagation science, recovery and translocation of terrestrial orchids', in K.W. Dixon, S.P. Kell, R.L. Barrett and P.J. Cribb (eds), *Orchid Conservotion*, pp. 259-288. Natural History Publications, Sabah, Borneo.

Rasmussen, H.N. (2002). Recent developments in the study of orchid mycorrhiza. *Plont ond Soil* **244**, 149-163.

Rasmussen, H.N. and Rasmussen F.N. (2009). Orchid mycorrhiza: implications of a mycophagous lifestyle. *Oikos* **118**, 334-345.

Roberts, P. (1999). Rhizoctonia-*forming fungi*. The Herbarium, Royal Botanic Gardens, Kew.

Roche, S.A., Carter, R.J., Peakall, R., Smith, L.M., Whithead, M.R. and Linde, C.C. (2010). A narrow group of monophyletic *Tulasnella* (Tulasnellaceae) symbiont lineages are associated with multiple species of *Chiloglottis* (Orchidaceae): Implications for orchid diversity. *Americon Journal of Botony* **97**, 1-15.

Sawyer, N.A., Chambers, S.M. and Cairney, J.W.G. (2003). Utilisation of inorganic and organic nitrogen sources by *Amanito* species native to temperate eastern Australia. *Mycologicol Research* **107**, 413-420.

Scade, A., Brundrett, M.C., Batty, A.L., Dixon, K.W. and Sivasithamparam, K. (2006). Survival of transplanted terrestrial orchid seedlings in urban bushland habitats with high or low weed cover. *Australian Journol of Botany* **54**, 383-389.

Schmidt, S. and Stewart, G.R. (1997). Waterlogging and fire impacts on nitrogen availability and utilisation in subtropical wet heathland (wallum). *Plant, Cell and Environment* **20**, 1231-1241.

Smith, S.E. and Read, D.J. (1997). *Mycorrhizal Symbiosis*, 2nd ed., Academic Press, London.

Stephen, R.C. and Fung, K.K. (1971). Nitrogen requirements of the fungal endophytes of *Arundino chinensis*. *Conodion Journol of Botony* **49**, 411-415.

Stefani, F.O.P., Guillaumin, J-J., Hamelin, R.C. and Bérubé, J.A. (2009). Multigene phylogeography and evolution of the phytopathogenic genus *Armillorio*. *Innoculum* **60**, 42-43.

Swarts, N.D., Sinclair, E.A., Francis, A. and Dixon K.W. (2010). Ecological specialization in mycorrhizal symbiosis leads to rarity in an endangered orchid. *Moleculor Ecology* **19**, 3226-3242.

Tamura, K., Dudley, J., Nei, M. and Kumar, S. (2007). MEGA4: Molecular Evolutionary Genetics Analysis (MEGA) software version 4.0. *Moleculor Biology ond Evolution* **24**, 1S96-1S99.

Taylor, D.L., Bruns, T.D., Szaro, T.M .and Hodges, S.A. (2003). Divergence in mycorrhizal specialisation within *Hexalectris spicoto* (Orchidaceae), a Nonphotosynthetic Desert Orchid. *Americon Journol of Botony* **90**, 1168-1179.

Taylor, D.L. and McCormick, M.K. (2008). Internal transcribed spacer primers and sequences for improved characterization of basidiomycetous orchid mycorrhizas. *New Phytologist* **177**, 1020–1033.

Tedersoo, L., Gates, G., Dunk, C.W., Lebel, T., May, T.W., Kõljalg, U. and Jairus, T. (2009). Establishment of ectomycorrhizal fungal community on *Nothofogus cunninghomii* seedlings regenerating on dead wood in Australian wet temperate forests: does fruit-body type matter? *Mycorrhizo* **19**, 403–416.

Warcup, J.H. (1988). Mycorrhizal associations of isolates of *Sebocino vermifero*. *New Phytologist* **110**, 227-231.

Weiß, M., Selosse, M.-A., Rexer, K.-H., Urban, A. and Oberwinkler, F. (2004). Sebacinales: a hitherto overlooked cosm of Heterobasidiomycetes with a broad mycorrhizal potential. *Mycologicol Reseorch* **108**, 1003-1010.

White, T.J., Bruns , T., Lee, S. and Taylor, J. (1990). Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenies. In: Innis MA, Gelfand DH, Sninsky JJ, White TJ (eds.) *PCR Protocols: A Guide to Methods ond Applicotions*. Academic Press, Inc.

Wright, M. (2007). Maximising the effectiveness of mycorrhizal fungi in the conservation of *Colodenio* taxa (Orchidaceae). PhD thesis, The University of Melbourne, Melbourne, Victoria.

Wright, M, Cross R, May T.W., Cousens R.D., and McLean C.B (2010). Taxonomic and functional characterisation of fungi from the *Sebocino vermifero* complex for symbiotic propagation of common and rare orchids in the genus *Colodenio*. *Mycorrhizo* **20**, *375-390*

Zettler, L.W. (1997). Terrestrial orchid conservation by symbiotic seed germination: techniques and perspectives. *Selbyona* **18**, 188-194.

A revision of *Goodia* (Fabaceae: Bossiaeeae)

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Introduction

Goodia Salisb. is a small genus of medium-sized to tall shrubs in the Australian-endemic tribe Bossiaeeae of the Fabaceae. It can be distinguished from the other six genera in the tribe by the combination of its pinnately trifoliolate leaves and many-flowered racemes. The genus extends across the southern third of Australia, including Western Australia, South Australia, New South Wales, Victoria, and Tasmania. In addition, in far eastern Australia there is a northern extension to its distribution, with its northernmost limit almost reaching to the Tropic of Capricorn in south-eastern Queensland.

Until recently, *Goodia* had been phylogenetically isolated from other genera in the tribe. Phylogenetic analyses of Crisp and Weston (1987) using morphological data placed *Goodia* basally, as did analyses of Crisp and Cook (2003), using molecular data. However, Thompson (2011), when erecting the new genus *Paragoodia* I.Thomps., suggested that *Goodia* and *Paragoodia* may be sister taxa. The single species of the new genus was formerly placed in *Muelleranthus* Hutch., but was not included in the molecular study. *Goodia* and *Paragoodia* are the only two genera in the tribe to have pinnately trifoliolate leaves. Their flowers, unlike those in *Muelleranthus*, *Aenictophyton* A.T.Lee and *Ptychosema* Benth., do not have a distinct hypanthium. *Platylobium* Sm. and *Bossiaea* Vent. differ from all other genera in having brown scales subtending inflorescences. *Goodia* differs from the rest of the tribe, generally speaking, in having early caducous bracts and bracteoles. Stipules are caducous in half of the species of *Goodia*, whereas in the rest of the tribe stipules are generally persistent. Thompson (2011) presents a revised key to the tribe which includes the new genus *Paragoodia*.

Taxonomic History: *Goodia lotifolia* Salisb. was described in 1806, followed soon after by *G. pubescens* Sims. *Goodia medicaginea* F.Muell. was described in 1858 and no further new species have been described since. *Goodia pubescens* has sometimes been treated as a variety of *G. lotifolia*, most recently by Ross (1997), while *G. medicaginea*, although currently recognised as distinct, has sometimes been treated as a synonym of *G. lotifolia* (eg. Bentham 1864; Weber 1986). Further details of the taxonomic history are presented in Ross (1997).

Abstract

A revision of the Australian-endemic genus *Goodia* Salisb. (Fabaceae: Bossiaeeae) is presented. Three new species are described: *Goodia macrocarpa* I.Thomps., *G. parviflora* I.Thomps., and *G. stenocarpa* I.Thomps. *Goodia lotifolia* Salisb. var. *pubescens* (Sims) H.B.Will. is returned to species status as *G. pubescens* Sims. A key to species and distribution maps are presented.

Keywords: morphology, taxonomy, biodiversity, flowering plants, peas.

Muelleria 29(2): 141-153 (2011)

Methods

This study was based on the examination of herbarium material with the aid of a dissecting microscope. Pressed flowers were reconstituted using hot soapy water to facilitate their examination. Specimens from AD, BRI, CANB, HO, MEL, NE, NSW, and PERTH were examined. In addition, several populations of *Goodia* in New South Wales and Victoria were examined in the field, and collections from these populations were made. Unless otherwise indicated, images presented in this paper were taken by the author using a Canon PowerShot A2000 IS digital camera.

Results

The results of this morphological study are presented in the taxonomic section below. In summary, the pattern of variation identified in *Goodia* calls for three new species to be described and a return to species status for *G. lotifolia* var. *pubescens* (Sims) H.B.Will.

The most useful characters for taxonomic purposes recognised in this study include: density of indumentum and orientation of hairs on axes; size and persistence of stipules; length of leaf-rachides, and the shape, apiculum size and indumentum of leaflets; lengths of pedicels, bracts, bracteoles and flower parts; degree of fusion of upper calyx-lobes; colour, marking pattern and relative lengths of petals; orientation of wing petals; number of ovules per ovary; size, shape and seed number of pods; the fleshiness of pod-valves and the prominence of their transverse venation; and the size of seeds and arils.

Taxonomy

Goodia Salisb., *Parad. Londin.* 1: t. 41 (1806)

Type: *G. lotifolia* Salisb.

Erect shrubs to c. 4 m high, sometimes slightly glaucous, with a variably dense, variably persistent indumentum on branches, stipules, leaves, inflorescence axes, pedicels and calyces. *Stipules* lanceolate, herbaceous, caducous or persistent. *Leaves* alternate, pinnately trifoliolate, to c. 80 mm long, with petiole one-third to two-thirds of the total length; rachis up to half the length of leaflets; leaflets petiolulate; lamina elliptic, obovate, cuneate or occasionally obcordate, entire, thin, pinnately veined, with reticulate veins inconspicuous, mid- to dark-green or blue-green, discolorous; base cuneate; apex obtuse, rounded or truncate, with apiculum absent or

Figure 1. Flowers. a. *G. lotifolia* (northern form); b. *G. lotifolia* (cultivated, southern form); c. *G. macrocarpa* (*I.R.Thompson 1339* MEL); d. *G. medicaginea* (cultivated, *I.R.Thompson s.n.*, MEL). Photo credit: a. Lachlan Copeland. Scale bars: a = 10 mm, b = 2 mm, c = 5 mm, d = 3 mm.

small; terminal leaflet slightly larger than lateral leaflets. *Inflorescences* racemose, terminal, sometimes exceeded by sympodial growth, indeterminate, typically with 10–30 flowers; flowers pedicellate, with pedicels divergent to spreading; basal bract and bracteoles ±herbaceous, generally caducous well before anthesis; bracteoles lanceolate to linear, opposite or subopposite, inserted in distal half of pedicel. *Calyx-lobes* slightly shorter to slightly longer than tube; upper lobes equal to or slightly shorter but broader than lower lobes, forming a tapering lip; lower lobes triangular to very narrow-triangular, sometimes with median lobe slightly longer and narrower; petals clawed, with standard claw longest; standard and wings of similar length, yellow with red and/or purple-brown markings; standard-limb orbicular to oblate, broad-cuneate to shallowly cordate, moderately emarginate, with a flare around a greenish, red-flecked throat; wings straight, slightly upcurved or rarely downcurved, slightly narrower than the keel; keel slightly to markedly shorter than wings, yellow-green, but often flushed reddish; keel-petals fused at distal end of lower margin, forming an obtuse or right angle with upper margin; stamens all fused into an adaxially open sheath, with the vexillary stamen sometimes less fused, and rarely becoming free; anthers dorsifixed, uniform in size, orange; ovary stipitate, glabrous except in *G. medicaginea*, (1–)2–6-ovulate; style upcurved with stigma minute, hardly broader than the slender style-terminus. *Pods* generally long-stipitate; body elliptic, oblong to narrow-oblong or rhomboidal in profile, moderately compressed, with a short beak, 1–6-seeded, glabrous at maturity; upper suture sometimes ridged or winged; valves coriaceous, remaining convex or flattening post-dehiscence; funicles 1–3 mm long, curved. *Seeds* ellipsoid, plump, black at maturity (dark-brown when nearly mature); aril 20–50% of length of seed, inserted laterally, with base ring-shaped, open at one end, with an overarching vertical lobe.

Notes on morphology: Examples of the morphology of *Goodia* are presented in figures 1 and 2.

Key to species

Note: Purple-brown petal markings appear purple in pressed specimens; these markings may become lost in older pressed specimens.

1 Abaxial surface of standard predominantly bright yellow; wings yellow distally; seeds with aril-base 1.2–2.5 mm long 2

1: Abaxial surface of standard mostly purple-brown grading to reddish orange towards margin; wings purple-brown distally; seeds with aril-base 0.5–1.2 mm long 4

2 Inflorescence axes, branchlets, and petioles glabrous or nearly so when mature; stipules early caducous ..... 1. ***G. lotifolia***

2: Inflorescence axes, current season branchlets and petioles with indumentum moderately dense when mature; stipules caducous or persistent 3

3 Stipules tending to persist, 1–3 mm long; wings 12–15 mm long; ovaries mostly 3–6-ovulate; body of pods oblong, to 40 mm long, with fine venation raised at least when dry (northern New South Wales and southern Queensland) ..... 2. ***G. macrocarpa***

3: Stipules early caducous, 5–7 mm long; wings 8–9 mm long; ovaries mostly 2-ovulate; body of pods c. elliptic, to 25 mm long, with venation obscure (Victoria and Tasmania) ..... 3. ***G. pubescens***

4 Stipules early caducous; abaxial surface of leaflets with persistent scattered, short appressed hairs; upper lip of calyx truncate or with sinus rounded or broadly obtuse; ovary and young fruit almost always with hairs along sutures; pods elliptic in profile ..... 4. ***G. medicaginea***

4: Stipules somewhat persistent; abaxial surface of leaflets becoming glabrous or with hairs persisting about midrib only; upper lip of calyx with sinus obtuse to acute; ovary glabrous; pods c. oblong in profile 5

5 Indumentum moderately dense, with hairs spreading, 0.5–1 mm long; calyx 3–5 mm long; pods 6–7 mm wide (Western Australia) ..... 5. ***G. stenocarpa***

5: Indumentum sparse, with hairs appressed, 0.2–0.5 mm long; calyx 2–3 mm long; pods 9–10 mm wide (Queensland) ..... 6. ***G. parviflora***

PETALS: Differences in the markings of the standard and wing petals separate the six species of *Goodia* into two groups of three, as shown in the key to species. These differences are evident in figures 1a–d. Flowers of *G. lotifolia* shown in profile in bud show a mostly yellow abaxial surface of the standard (Fig. 1a), whereas the profile of flowers of *G. medicaginea* shows the abaxial surface to be be reddish all over (Fig. 1d). A similar distinction between species in extent of red pigmentation is evident for the adaxial surface. The wing is yellow distally in *G. lotifolia* (Figs 1a–c), whereas it is purple-brown in *G. medicaginea* (Fig. 1d).

The three species with a predominantly bright yellow standard commonly have longer flowers than the other three species; however, flowers of *G. medicaginea* may be longer than those of *G. pubescens* and, less often, of *G. lotifolia*.

LEAVES: Smaller leaves of short lateral branches may have a very short rachis and superficially appear to be digitately trifoliolate. This is most commonly seen in *G. pubescens* and in southern forms of *G. lotifolia*.

INFLORESCENCES: The more basal buds of inflorescences often abort and fall before anthesis. The prominent abscission scars of bracts mark their position. Similarly, a cluster of apical buds that fail to develop beyond a rudimentary size are sometimes evident. Racemes are all terminal in that they terminate branches. However, they sometimes appear to be axillary because of extensive sympodial growth (shoot development from the axil of the terminal leaf). Such racemes are variously called pseudoaxillary or leaf-opposed.

PODS: A comparison of pods and seeds of all species are presented in figures 2a, 2b and 2d. The scale is slightly larger in figure 2b compared to 2a. In general, pods of the smaller flower group are smaller than in the large flowered group. The nature of the connection of the aril to the funicle is shown in figure 2c. This arrangement occurs in all genera of the tribe Bossiaeeae. In figure 2d, the different lengths (top row longer) of the base of the aril is the main difference of significance. The greater overhang of the lobe in *G. medicaginea* and *G. stenocarpa* (bottom row) is also a significant difference.

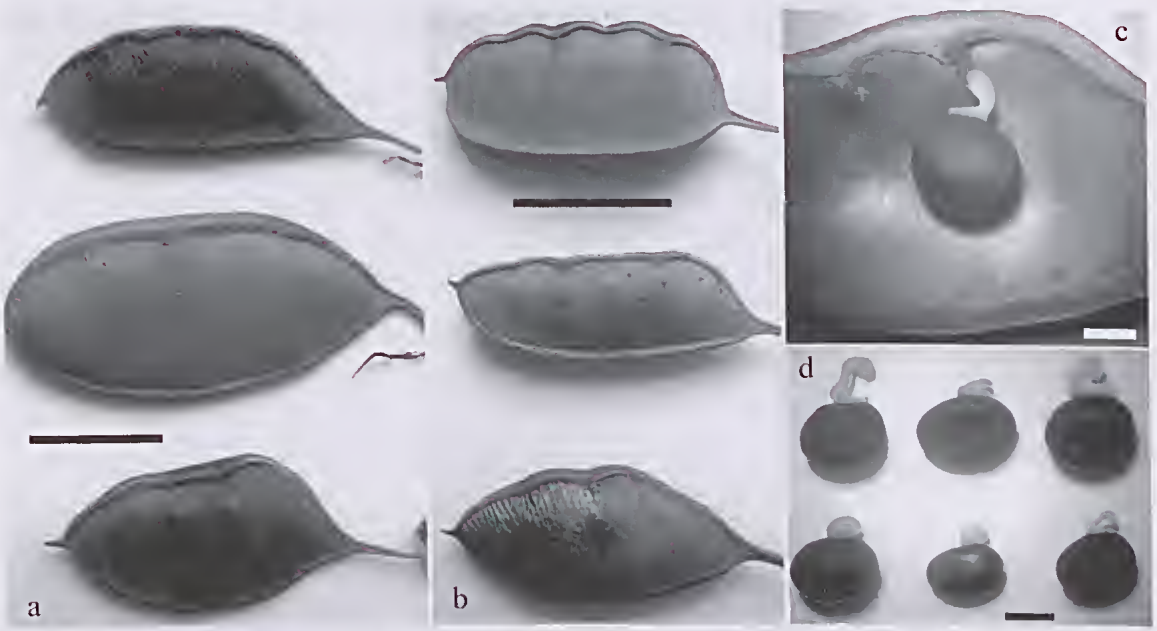

Figure 2. a–b. Pods: a. (top to bottom) *G. latifolio* (*A.C.Beouglehale 67453* MEL), *G. mocrocarpo* (*A.R.Beon 23387* BRI), *G. pubescens* (*J.H.Ross 3702* MEL); b. (top to bottom) *G. parviflara* (*A.R.Beon 10159* BRI), *G. stenacarpo* (*B.Archer 1441* MEL), *G. medicagineo* (*J.Strudwick 252* MEL). c–d. Seeds: c. *G. lotifolio* (New South Wales southern highlands form), pad and attached seed (*I.R.Thampsan 1199* MEL); d. (L to R) top row: *G. latifolia* (*A.H.A.Beetham* MEL), *G. macracarpa* (*Wilcox* MEL), *G. pubescens* (*J.H.Rass 3703* MEL); bottom row: *G. medicagineo* (*B.Bainbridge s.n.* MEL), *G. stenacarpa* (*B.Archer 1441* MEL), *G. parviflara* (*A.R.Beon 10159* BRI). Scale bars: a–b = 10 mm, c–d = 2 mm.

The different degrees of arching of the vertical lobe of the aril in these examples is not significant; this feature varies within species.

1. *Goodia lotifolia* Salisb., *Parad. Londin.* 1: t. 41 (1806)

Type: Cult. Seed collecting locality unknown [possibly Arthurs Seat in Victoria in April 1802], *P.Good*, 1802; icono: t. 41, *loc. cit.*

Goodia latifolia as given by Colla in *Hortus Ripulensis* 1: 62 (1824) is probably an orthographical error for *G. lotifolia*.

Shrubs to c. 4 m high, with a sparse appressed pubescence on new growth, becoming glabrous or very sparsely hairy; hairs ±appressed, to 0.3 mm long. *Stipules* early caducous, narrow-lanceolate, 1–8 mm long, 1–1.5 mm wide. *Leaves*: petiole 30–70% of total length; rachis to c. 10 mm long; lamina of terminal leaflet elliptic to obovate, 10–30 mm long, 6–30 mm wide, 3–10 times length of rachis, with l:w ratio mostly 1–1.5; apex rounded, truncate or emarginate, with apiculum minute or to c. 1 mm long; upper surface glabrous; lower surface soon glabrescent or short appressed hairs somewhat persistent. *Inflorescence axes* to c. 14 cm long; bracts 1.5–5 mm long; pedicels 3–12 mm long; bracteoles 1–3 mm long. *Calyx* 3.5–7 mm long, glabrous or sparsely hairy; upper lip with sinus broadly obtuse to acute, or occasionally subtruncate, mostly 0.5–1.5 mm deep, 1–2.5 mm wide, lower lobes (1.5–)2.5–3.5 mm long, with median lobe sometimes longer; standard 10–16 mm long, 12–18 mm wide; claw 3–6 mm long; limb c. circular or oblate; adaxial and abaxial surfaces bright yellow except for a red flare to 2 mm wide surrounding throat or as patches at sides of throat, purple-brown pigment absent or in small amounts; throat 1–3 mm wide, squarish; wings 8–14 mm long, 3–5 mm wide, yellow throughout, or variously marked red basally, purple-brown or grey-brown basally and centrally; keel 7–12 mm long, 3–5 mm wide, yellow-green throughout or flushed red at apex or more extensively; anthers 0.6–1 mm long; ovary (1–)2–4(–5)-ovulate, style 2.5–4 mm long. *Pods*: stipe 5–15 mm long; body rhomboid-elliptic, obovate, or occasionally oblong in profile, 15–35 mm long, 7–13 mm wide, mid-brown or dark reddish-brown, 1–4-seeded; upper suture with a ridge or wing to c. 1.5 mm high; apex rounded to acute, with beak 1–3 mm long; outer valve surface with venation conspicuously raised when dry, inner valve surface with suture zone 1–2 mm wide, undulate when 3 or more-ovulate; funicle slightly curved. *Seeds* 3–5 mm long; aril 1.2–2.5 mm long, 1.2–2 mm high, with base 1.2–2.5 mm long; lobe not usually overhanging base, with tip mildly curved.

***Selected specimens from c. 300 examined*: QUEENSLAND**: First Creek towards Mackenzies [near Kilcoy], *L.Leichhordt*, 1843 (NSW); Harland Rd, Mt Glorious, *A.R.Beon 2159*, 1B.viii.1990 (BRI, MEL1597059); 0.3 km along K break, Mt Mee State Forest, near Mt Mee, *A.R.Beon 14394*, 3.xii.199B (BRI). **NEW SOUTH WALES**: The Scrub picnic area off the Colongon Fire trail, c. 18 km SE of Tenterfield, *R.G.Coveny 16588 & A.J.Wholen*, 15.x.1993 (AD, BRI, CANB, HO, MEL2B1231, NSW); Giro State Forest on the Walcha–Gloucester Rd, *A.R.Beon 11469*, 10.xii.1996 (BRI, MEL24936B, NSW); Road to TV telecommunication towers, c. 7 km W by road from Princes Hwy, Middle Brother National Park, *I.R.Thompson 1349*, 26.xi.2010 (AD, BRI, CANB, MEL); c. 500 m up steep slope from Marble Arch, Deua National Park, *T.R.Lolly 171*, 24.x.1993 (CANB, NE, NSW); Mt Cambewarra, *E.F.Constoble s.n.*, 7.xii.1950 (NSW); 0.5 km E of Junction of Mellion Ck and Tuross R., *M.D.Crisp 2190*, 25.ix.1976 (AD, CANB); 0.5 km S of Mt Armour, Kanangra-Boyd National Park via Oberon, *A.R.Beon 17142*, 19.xii.2000 (BRI); NE of Mt Armour, Armour Range, *J.Pickord 402 & S.Pickord*, 21.ix.1969 (NSW); Bendethera Caves fire trail, 63 km SSW of Braidwood, *R.G.Coveny 5970 & A.N.Rodd*, 15.i.1975 (MEL2090167, NSW); Tallaganda State Forest, road to Parkers Gap from Captains Flat, *A.M.Lyne 1606*, 29.x.1995 (CANB, MEL2090170, NSW). **AUSTRALIAN CAPITAL TERRITORY:** Slopes of Mt Tidbinbilla on path to Kangaroo Gap, *N.T.Burbidge 5593*, 17.iii.1957 (CANB, MEL). **VICTORIA**: Warburton, *J.C.H.Adler*, 21.ix.1921 (MEL663BB1); near the Latrobe R. between Neerim and Fumina, *A.H.A.Beethom*, xii.1950 (MEL105B073); Mt Oberon, Wilsons Promontory, *J.Golbroith*, 20.iii.1957 (MEL594055); Burgess Rd, 6.4 km E of junction with Link Rd, Bunyip State Park, *P.C.Jobson 3727 & J.C.Reid*, 7.ix.1995 (AD, BRI, CANB, MEL20270B9, NSW); Wait-a-while track, SE of Lavers Hill, *K.Mocforlone 178*, 9.x.1996 (AD, CANB, HO, MEL2034975, NSW). **TASMANIA**: Cape Barren Island, *J.S.Whinroy 618*, 27.x.1973 (MEL529377); Road into Great Musselroe R., S section of "The Branches", *M.Visoiu 416*, 12.i.200B (CANB, HO); Road to Jetty, Bridport, *D.M.Poton*, 6.ix.1948 (HO); Mt Wellington, Lower Valley, *L.Rodwoy 173*, xii.1927 (HO); Deceitful Cove, George Town, *A.M.Buchonon 13442*, 28.ix.1993 (HO).

Flowering period: Flowers mostly late winter to mid spring.

Distribution and habitat: Occurs in south-eastern Queensland, eastern New South Wales, southern Victoria, and Tasmania (Fig. 3). Grows in medium to tall forest.

Notes: There is a moderate degree of geographic variation in *G. lotifolia*; however, the variation appears to be insufficiently discrete to warrant infraspecific taxonomic recognition. In northern localities, north of Taree in New South Wales and extending into Queensland, the wing and keel petals are generally more extensively marked red and purple-brown, the standard throat is broader and the lower lobes of the calyx generally are not longer than the upper lobes. In populations in the southern highlands of New South Wales, eg. Cambewarra Mountain, the indumentum tends to be more persistent, flowers tend to be smaller, pods have fewer but larger seeds and the funicle is entirely red, ie. oriented so that the white-granular part is not evident (Fig. 2c). In populations in far southern New South Wales, Victoria and Tasmania, flowers have relatively long wing and keel petals with less extensive red and purple-brown markings, the wings tend to be downcurved, stipules are longer, and the apiculum of leaflets is generally more prominent.

Spongiose tissue arising from the inner surface of pod valves and surrounding seeds has occasionally been recorded in *G. lotifolia*. This appears to be homologous to the partitions seen in some species of *Bossiaea*, eg. *B. heterophylla*.

Typification: The iconotype is a drawing of a plant grown from seed collected by Peter Good. However, the provenance of the seeds is not known. The only possible localities appear to be King Island in Bass Strait, Port Phillip Bay in Victoria and Port Jackson (Sydney area) in New South Wales. In all cases the times Good was present, April to June, were unlikely times for seeds to be remaining on plants, although a summer flowering, following the normal spring flowering, is known to occur in *G. lotifolia*. The protologue describes the plants grown from seed, and it suggests that the southern form was collected based on the description of long stipules and the standard with a pair of red markings above the claw (as distinct from a continuous semicircular flare).

2. *Goodia macrocarpa* I.Thomps., *sp. nov.*

A G. pubescens *Sims stipulis persistentibus brevioribus, vexillo longiore, sinu calycum latiore, leguminibus longioribus, venis expressis differt; a* G. lotifolia *Salisb. plantis pubescentibus, stipulis persistentibus, leguminibus plerumque longioribus differt.*

Type: New South Wales. Pinanpinga fire trail, Knorrit State Forest, c. 25 km W of Wingham, *A.R.Bean 23387*, 30.xii.2004; holotype: BRI 698082.

Shrubs to c. 3 m high, with a moderately dense, persistent pubescence on current season's growth; hairs divergent or appressed, to c. 0.3 mm long. *Stipules* somewhat persistent, narrow-lanceolate, 1–3 mm long, 0.3–0.5 mm wide. *Leaves*: petiole 40–50% of total length; rachis to c. 10 mm long; lamina of terminal leaflet narrow-elliptic to elliptic, 20–30 mm long, 15–20 mm wide, 3–8 times length of rachis, with l:w ratio 1.6–2; apex rounded, with apiculum minute; upper surface glabrous or nearly so; lower surface usually with

Figure 3. Distributions in south-eastern Australia of a. *Goodia lotifolia*, b. *G. macrocarpa*, and c. *G. pubescens*.

scattered short appressed hairs. *Inflorescence axes* to c. 9 cm long; bracts 1.5–4 mm long; pedicels 3–10 mm long; bracteoles 1–2 mm long. *Calyx* (4–)4.5–7 mm long, with hairs sparse to scattered, appressed; upper lip with sinus acute to obtuse, 0.5–1 mm deep, 1.5–3 mm wide; lower lobes 2–3 mm long, all similar in length; standard 12–16 mm long, 15–18 mm wide; claw 4–5 mm long; limb oblate; adaxial and abaxial surfaces bright yellow except for a red flare to 2 mm wide surrounding throat, purple-brown pigment absent or in minute amounts; throat 4–5 mm wide, somewhat rounded at sides, with 2 triangular points at summit; wings 12–15 mm long, 3.5–4.5 mm wide, red in proximal two-thirds, yellow in distal third; keel 10–11 mm long, 4–4.5 mm wide, with a light red flush in distal half to two-thirds, without a line of red adjacent to lower margin; anthers c. 1 mm long; ovary 3–6-ovulate, style 3.5–4 mm long. *Pods*: stipe 10–15 mm long; body oblong to oblong-elliptic, mostly 20–40 mm long, 10–15 mm wide, brown, mostly 3 or 4-seeded; reddish-brown; upper suture with a low broad ridge to c. 0.8 mm high; apex obtuse to subacute, with beak 1–2 mm long; outer valve surface with venation slightly raised when dry; inner valve surface with suture zone 1–1.5 mm wide, ±straight; funicle curved. *Seeds* c. 4 mm long; aril 1.5 mm long, c. 1.2 mm high, base 1.2–1.5 mm long, lobe not or only slightly overhanging, with tip c. 0.5-1 mm above seed-surface.

***Selected specimens of c. 35 examined*: QUEENSLAND:** "The Panorama" at Gilston, *G.Leiper*, 25.xi.2004 (BRI); Boundary of SF735, Drummer and Border section of Mt Barney National Park, *P.Grimshaw G993 & G.Turpin*, 28.ix.1994 (BRI); Numinbah Forest Reserve, N end of Springbrook Plateau, *D.A.Halford Q9118*, 29.vii.2006 (BRI, MEL2332467); Canungra to Mt Tamborine Rd, c. 2 km S of Mt Tamborine, *W.J.F.McDonald 1496 & W.G.Whiteman*, 29.vii.1976 (BRI). **NEW SOUTH WALES:** Coffs Harbour, *J.H.Maiden & J.L.Boorman*, xi.1903 (NSW); Track to Nothofagus Mountain, c. 11.3 km N of Woodenbong, *R.Coveny 5172*, 5.ix.1973 (BRI, NSW); McPherson Range, Mt Lindsay State Forest, *I.R.Telford 26B4*, 4.x.1970 (CANB); Nymboi-Binderay National Park, 5.0 km along Pilot Knob Fire Trail from turn-off on Black Mountain Rd, *M.D.Crisp 10362*, 24.xi.2006 (CANB); Welsh's Rd, Clouds Creek SF, N of Dorrigo, *A.R.Bean 16857*, 9.ix.2000 (BRI, NSW); c. 1 km along Pinanpinga Fire Trail, off Knodingbul Forest Rd, Knorrit State Forest, *I.R.Thompson 1340*, 25.xi.2010 (MEL).

Flowering period: Main flowering time late winter to early spring; also flowers late spring to summer.

Distribution and habitat: Occurs in far south-eastern Queensland S of Tamborine, and in north-eastern New South Wales as far S as Wingham (Fig. 3). Grows in tall forest.

Etymology: The epithet refers to the relatively large pods (From Greek: *macro*-, large, and *carpos*, fruit).

Figure 4. *Goodia macrocarpa*. a. portion of holotype (*A.R.Bean 23387* BRI); b. developing raceme; c. flower (b. & c. *R.Coveny 5172* MEL). Scale bars: a = 10 mm, b–c = 5 mm.

Notes: The only other species of *Goodia* with a similar indumentum to that of *G. macrocarpa* is *G. pubescens*. These two species are separated by over 1000 km. *Goodia macrocarpa* has the largest fruit in the genus and is the only species with wings that have bright red markings rather than purple-brown or grey-brown (Fig. 1c). The pubescence is not obvious to the naked eye except on new growth, but examination under low power shows that the indumentum is significantly denser than ever seen in *G. lotifolia*. Stipule persistence also distinguishes *Goodia macrocarpa* from *G. lotifolia*, *G. pubescens* and *G. medicaginea*. Compared to all other species of *Goodia*, the stipules are relatively short, narrow and hairy. *Goodia macrocarpa* occurs in similar habitats to that of *G. lotifolia*. Some features of the morphology of *G. macrocarpa* are presented in figure 4.

3. *Goodia pubescens* Sims, *Bot. Mag.* 32: t. 1310 (1810).

Goodia lotifolia var. *pubescens* (Sims) H.B.Will., *in* A.Ewart, *Fl. Victoria* 658 (1931)

Type: Tasmania. Locality unknown, iconotype: t. 1310 *loc. cit.*

Goodia subpubescens Sweet, *Hort. Brit.* 110 (1826), *nom. nud.*

Shrubs to c. 2 m high, with a moderately dense to dense, persistent pubescence on current season's growth; hairs spreading to appressed, 0.3–0.5 mm long. *Stipules* early caducous, oblong-lanceolate, 3–7 mm long, c. 1 mm wide. *Leaves*: petiole 40–50% of total length; rachis to c. 8 mm long, sometimes not developed in smaller leaves; lamina of terminal leaflet narrow-elliptic to elliptic or narrow-obovate to obovate, 10–40 mm long, 6–20 mm wide, 4–12 times length of rachis (or rachis hardly developed), with l:w ratio 1.4–2.5; apex rounded, truncate or retuse, with apiculum absent or minute; upper surface glabrous or with sparse to scattered, loosely appressed to antrorse divergent hairs; lower surface with scattered appressed hairs. *Inflorescence axes* to c. 9 cm long; bracts 2–3 mm long; pedicels 3–8 mm long; bracteoles c. 2 mm long. *Calyx* 4–6.5 mm long, moderately hairy, with hairs appressed; upper lip with sinus acute, 0.8–1.2 mm deep, 1–1.5 mm wide; lower lobes 2–4 mm long, with median lobe generally distinctly longer than lateral lobes; standard 9–12 mm long, 10–14 mm wide; claw 3–4 mm long; limb orbicular to oblate, adaxial and abaxial surfaces bright yellow with a red flare to c. 2 mm wide mostly surrounding throat, purple-brown pigment present in flare in moderate amounts and radiating a short distance along nerves; throat c. 2.5 mm wide, squarish; wings 8–10 mm long; 3–4 mm wide, purple-brown in proximal half, yellow in distal half; keel 7–8 mm long, c. 3 mm wide, red nearly throughout; anthers c. 0.7 mm long; ovary mostly 2-ovulate, style 2.5–3 mm long. *Pods*: stipe 3–10 mm long; body narrow-elliptic to elliptic, 10–20 mm long, 9–11 mm wide, reddish-brown, mostly 2-seeded; upper suture usually with a ridge to c. 1 mm high; apex obtuse to subacute, with beak 1–2 mm long; outer valve surface with veins generally obscure when dry, inner valve surface with suture zone c. 1 mm wide, not undulate; funicle slightly curved. *Seeds* c. 4 mm long; aril 1.5–2 mm long, 1.5–2 mm high, with base 1.2–2 mm long; lobe not overhanging, mildly curved.

Selected specimens of c. 70 examined: **VICTORIA**: Junction of Acheron Way and Marysville Rd, 10 km SW of Marysville, *P.C.Jobson 3279, A.W.Douglas & J.H.Ross*, 27.x.1994 (MEL2037933, NSW); Halls Gap–Mt Victory Rd, 3 km SW of Halls Gap, Grampians National Park, *J.H.Ross 3799*, 22.ix.1996 (AD, HO, MEL2034885); Kaanglang Rd, 6 km SSE of Forrest, *S.G.Harris 72*, 10.x.1985 (AD, CANB, HO, MEL2090174, NSW); Along the Mt Richmond to Greenwald Rd, S of the Surry R., c. 1.5 km E of Wrights Swamp, *H.I.Aston 748*, 22.x.1960 (MEL720961); Redmans Rd, 12 km SE of Halls Gap, *A.C.Beauglehole 67076*, 7.xii.1979 (MEL646800). **TASMANIA**: Archers Sugarloaf, *A.Moscal 12499*, 25.ii.1986 (HO, MEL722665); Cataract Gorge, Launceston, *F.E.Burbury*, 15.ix.1911 (HO); Kingston–Longley Rd, *F.H.Long 965*, 2.xi.1931 (HO); Woods Lake, Central Plateau, *A.Moscal 719*, 10.iii.1981 (HO, MEL596697); Cummings Creek, East Arm, East Tamar, *A.M.Buchanan 16744*, 20.ix.2007 (HO).

Flowering period: Flowers in spring.

Distribution and habitat: Occurs in southern Victoria and Tasmania (Fig. 3). Grows in forest.

Notes: Apart from features indicated in the key, *G. pubescens* can often be distinguished from *G. macrocarpa* and *G. lotifolia* by the relatively short rachis and relatively narrow leaflets of its leaves, by the hairs that sometimes persist on the upper surface of leaves, by the median calyx-lobe which is longer than the lateral ones by a greater amount, and by the pods which are less prominently ridged along the upper margin. In Tasmania, plants generally have smaller leaves, flowers and seeds, and the pods have a shorter stipe.

4. *Goodia medicaginea* F.Muell., *Fragm.* 1: 10 (1858)

***Type*:** Victoria. Locality unknown [Australia Felix], *F.Mueller*; lectotype: MEL 237139, *fide* J.H.Ross, *Muelleria* 10: 6 (1997).

Shrubs to c. 3 m high, with a sparse to moderately dense, variably persistent pubescence on current season's growth; hairs appressed or divergent, to 0.3 mm long. *Stipules* early caducous, oblong-lanceolate, 2–5 mm long, c. 1 mm wide. *Leaves*: petiole 30–50% of total length; rachis to 18 mm long; lamina of terminal leaflet elliptic, orbicular, oblate, or obovate, 10–30 mm long, 8–25 mm wide, (1.5–)2–6 times length of rachis, with l:w ratio 0.9–1.5(–2); apex obtuse to truncate or retuse, with apiculum to c. 0.5 mm long; upper surface glabrous; lower surface with persistent short, appressed hairs. *Inflorescence axes* to c. 14 cm long, mostly < 10 cm long; bracts 2–6 mm long; pedicels 3–10 mm long; bracteoles 1.5–4 mm long. *Calyx* 3–5.5 mm long, hairy; upper lip c. truncate or with sinus broadly rounded or broadly obtuse, to 0.7 mm deep, 1.5–2.5 mm wide; lower lobes 1–2.5 mm long, all similar in length; standard 7–12 mm long, 8–12 mm wide, claw 3–5 mm long, limb oblate, adaxial surface yellow or orange-yellow with a red and purple-brown flare c. 2 mm wide surrounding throat, abaxial surface with purple-brown to orange-red zone extending almost to margin; throat 2–2.5 mm wide, squarish; wings 6–10 mm long, c. 3 mm wide, purple-brown throughout; keel 6–8.5 mm long, c. 3 mm wide, red throughout; anthers c. 0.6 mm long; ovary with scattered hairs, mostly on sutures (and variably persistent as fruit develops), 2- or less often 3–4-ovulate, style 2–3.5 mm long. *Pods*: stipe 5–15 mm long; body narrow-elliptic to elliptic to sub-rhomboid, 10–25 mm long, 7–12 mm wide, glabrous, reddish-brown, 2(or 3)-seeded; upper suture not ridged, or occasionally with ridge to c. 0.5 mm high; apex obtuse to subacute, with beak c. 0.5–1 mm long (slender style remnant sometimes contributing a further 1 mm); outer valve surface with raised venation usually evident when dry, inner valve surface with suture zone c. 0.8 mm wide, undulate; funicle moderately curved. *Seeds* 3–4 mm long; aril 1.5–2 mm long, c. 1 mm high, with base

Figure 5. Distributions of a. *Goodia medicaginea*, b. *G. stenocarpa*, and c. *G. parviflara*.

0.8–1 mm long; lobe overhanging base and strongly curving down to seed surface.

***Selected specimens of more than 300 examined*: WESTERN AUSTRALIA:** S of Pine Hill Campsite, 20 km N of Mt Ragged, E of Esperance, *D.J.Edinger 6069*, 33.x.2006 (PERTH); Cobertup Nature Reserve, *G.J.Keighery 15439*, 28.viii.1998 (PERTH); Parmango Rd, 91.9 km E of Condingup, *B.Archer 2391*, 2.x.2003 (CANB, MEL2221248 & MEL2221249, PERTH); Ongerup, *K.Newbey 334*, 19.viii.1962 (PERTH). **SOUTH AUSTRALIA:** Koondoolka, North-West Section of Gawler Range, *J.Z.Weber 3077*, 23.ix.1972 (AD, MEL2090101); Kellidie Bay Conservation Park, Eyre Peninsula, *S.Williams CBP179*, 6.ix.2000 (AD); Naracoorte Cave Conservation Park, intersection of Mt Gambier and Caves Rds, *J.H.Ross 3697*, 14.xii.1995 (MEL2030313, MEL2030314); Near mouth of gorge of Arcoona Ck, Gammon Ra., *H.Eichler 12674*, 17.ix.1956 (AD); Mt Torrens–Tepko Rd, Rockleigh, *K.H.Brewer 17*, 18.xii.2005 (AD). **NEW SOUTH WALES:** Lange's property, 10 km W of West Wyalong, *C.Betteridge*, 21.viii.1973 (AD, NSW); W of Mt Brogden, Cocopara National Park, c. 20 km E of Griffith, *M.Fox B208511 & H.Fallding*, 14.ix.1982 (NSW). **VICTORIA:** Killawarrah Forest, near Wangaratta, *R.Thomas 637*, 1993 (MEL2025913); 2.5 km WSW of Mt Napier, *A.C.Beauglehole 56BB9 & L.K.M.Elmore*, 16.x.1977 (MEL1508158); Tallageira State Forest, *J.A.Jeanes 1240*, 13.x.2002 (MEL2199221).

***Flowering period*:** Flowers late winter to spring.

***Distribution and habitat*:** Occurs in southern Western Australia, southern South Australia, New South Wales and Victoria (Fig. 5). Grows in woodland and open forest.

***Notes*:** Two features that usually readily identify *G. medicaginea* are the truncate upper calyx-lip and the scattered hairs on the ovary and developing pod. The scattered hairs are predominantly in the proximal half of the upper suture, and are virtually always developed. However, specimens with glabrous ovaries have been recorded from the Cocopara and Warrumbungle Ranges in New South Wales. The hairs persist for some time following flowering, but are generally lost at fruit maturity. Also distinctive in *G. medicaginea* are the branches which commonly become reddish and finely rugose or verrucose with age. Leaves have a relatively long rachis, particularly when compared to those of *G. pubescens* in Victoria where the two species co-occur. In the Flinders Ranges of South Australia, plants often have relatively large leaves with exceptionally long leaf-rachides.

5. *Goodia stenocarpa* I.Thomps., *sp. nov.*

A G. medicaginea *F.Muell. pilis longioribus patentibus, foliolis infeme et calycis propemodo glabris, leguminibus oblongis differt.*

***Type*:** Western Australia. New Norseman–Hyden Track, 31 km W of Norseman Post Office, *B.Archer 1309*, 8.viii.1999; holotype: MEL 2068447; isotype: PERTH *n.v.*

Shrubs to c. 1 m high, with a moderately dense, persistent pubescence on current season's growth; hairs spreading, 0.6–1 mm long. *Stipules* somewhat persistent, lanceolate, to 7 mm long, 1.5 mm wide. *Leaves*: petiole 50–60% of total length; rachis 2–7 mm long; lamina of terminal leaflet obovate, 10–25 mm long, 8–20 mm wide, with l:w ratio 1–1.4, 3–5 times length of rachis; apex rounded, truncate or retuse, with apiculum to c. 0.3 mm long, sometimes triangular; upper surface glabrous; lower surface glabrous except for a few hairs along midrib and sometimes margin. *Inflorescence axes* to c. 10 cm long; bracts c. 5 mm long; pedicels 4–8 mm long; bracteoles 1–4 mm long. *Calyx* 4–5 mm long, glabrous or nearly so except for margins; upper lip with sinus acute, c. 0.8 mm deep, c. 1 mm wide; lower lobes 2–3 mm long, with median lobe generally longest; standard 8–9 mm long, 9–10 mm wide, with claw 2.5 mm long, limb strongly oblate, adaxial surface yellow or orange-yellow with a red and purple-brown flare c. 2 mm wide surrounding throat, abaxial surface with purple-brown to orange-red zone extending almost to margin; throat c. 2 mm wide, squarish; wings c. 7 mm long, 2 mm wide, purple-brown ±throughout; keel c. 6 mm long, 2.5 mm wide, red throughout; vexillary stamen becoming free; anthers c. 0.5 mm long; ovary 4-ovulate, style 1.5–2 mm long. *Pods*: stipe 3–6 mm long; body oblong or oblong-elliptic, 12–20 mm long, 5–7 mm wide, mid-brown, mostly 3- or 4-seeded; upper suture not or only slightly ridged; apex obtuse to subacute, with beak c. 0.5 mm long; outer valve surface with venation faintly raised when dried; inner valve surface with upper suture c. 0.5 mm wide, straight; funicle strongly curved. *Seeds* 3–4 mm long; aril c. 1 mm long, c. 0.6 mm high, with base c. 0.5 mm long; lobe strongly overhanging and strongly curving down to seed surface.

***Selected specimens of c. 10 examined*: WESTERN AUSTRALIA**: Cave Hill Track, 37 km SW of Widgiemooltha Roadhouse, *B.Archer 2566*, 9.x.2005 (CANB, MEL2288648, PERTH); On "new" Hyden–Norseman Rd, 29.7 km W of Norseman, *W.O'Sullivan 424*, 29.viii.1998 (MEL2090103, PERTH); Lake King, *H.Steedman*, xi.1930 (PERTH); c. 1.6 km S of Hatter Hill, *K.R.Newbey 3359*, 3.ix.1970 (PERTH).

Flowering period: Flowers late winter to spring.

***Distribution and habitat*:** Occurs in inland parts of southern Western Australia between Lake King and Widgiemooltha, north of Norseman (Fig. 5). Grows in red clay-loam, over limestone, in *Eucalyptus flocktoniae* (Maiden) Maiden woodland.

***Etymology*:** The epithet refers to the relatively narrow pods (From Greek: *steno*, narrow and *carpos*, fruit).

***Notes*:** *Goodia stenocarpa* is perhaps closest in morphology to *G. medicaginea* which occurs relatively close by in southern Western Australia, but they differ markedly, especially in indumentum and fruit morphology. All fruiting material seen of *G. stenocarpa* has had a relatively high fruit set. Based on relatively few samples, it appears that the vexillary stamen is free or at least becomes free during flowering. This has not been recorded before in tribe Bossiaeeae. Based on photographs provided by a collector, *B. Archer*, *G. stenocarpa* differs from other species of *Goodia* in having a more spreading habit. Details of the inflorescence, persistent stipules and the spreading indumentum and pods are presented in figure 6.

6. *Goodia parviflora* I.Thomps., *sp. nov.*

A G. medicaginea *F.Muell. pedicellis brevioribus, floribus minoribus, calycis glabris, foliolis glabris inferne, ovariis glabris, leguminibus oblongis differt.*

***Type*:** Queensland. Sixteen Mile LA, Coominglah State Forest, SW of Monto, *A.R.Bean 10159*, 19.iii.1996; holotype: MEL 2031555; isotype: MEL 2031556; BRI 654615 (2sheets).

Shrubs to c. 1 m high, with a sparse indumentum on new growth, becoming glabrous or nearly so; hairs appressed, to c. 0.2 mm long. *Stipules* somewhat persistent, lanceolate, to 5 mm long, 0.6–1 mm wide. *Leaves*: petiole 1/3–1/2 of total length; rachis 3–10 mm long; lamina of terminal leaflet elliptic, orbicular, oblate, or obovate, 10–25 mm long, 8–25 mm wide, with l:w ratio 1–1.3, 3–5 times length of rachis; apex rounded, apiculum to c. 0.5 mm long; upper surface glabrous; lower surface glabrous or with occasional hairs on midrib and margins. *Inflorescence axes* to c. 6 cm long; bracts c. 2 mm long; pedicels 2–3 mm long; bracteoles c. 1 mm long. *Calyx* 2–3.5 mm long, glabrous or nearly so; upper lip with sinus obtuse to c. 0.5 mm deep, 1 mm wide; lower lobes c. 1 mm long, all similar; standard 5–6 mm long, c. 5 mm wide, including claw 3–4 mm long, limb oblate, adaxial surface yellow or orange-yellow with a red and purple-brown flare c. 2 mm wide surrounding throat, abaxial surface with purple-brown

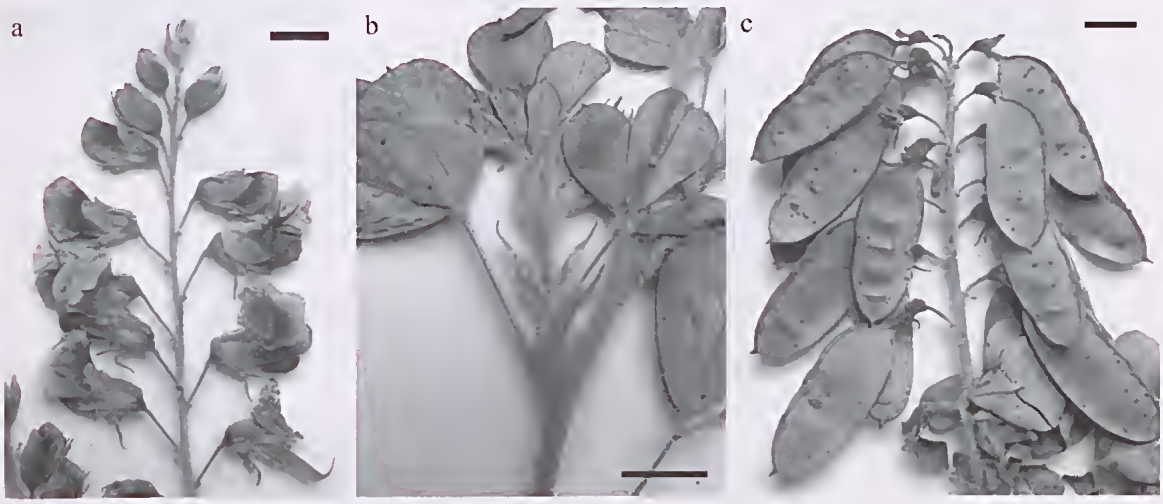

Figure 6. *Goodia stenocarpa*. a. inflorescence; b. stipules and indumentum (a. & b. *B.Archer 1309* MEL); c. developing pods (*B.Archer 2566* MEL). Scale bars: a–c = 5 mm.

to orange-red zone extending almost to margin; throat c. 1.5 mm wide, squarish; wings 5–6 mm long, 1.5 mm wide, purple-brown ±throughout; keel c. 5 mm long, c. 2 mm wide, red throughout; anthers c. 0.5 mm long; ovary 4-ovulate, style 1–1.5 mm long. *Pods*: stipe 5–8 mm long, body c. oblong in profile, 15–22 mm long, c. 10 mm wide, glabrous, tan, up to 4-seeded; base mostly obtuse, upper suture with a wing to c. 0.5 mm high; apex rounded, with beak c. 0.5–1 mm long; outer valve surface with venation usually faintly raised when dry; inner valve surface with suture zone c. 1 mm wide, undulate; funicle strongly curved. *Seeds* 3 mm long; aril 1.3 mm long, c. 1 mm high, with base c. 1 mm long; lobe slightly overhanging, moderately curved.

Selected specimens of c. 8 examined: **QUEENSLAND**: Abbeywood via Hivesville near Kingaroy, *D.E.Benhom*, 26.x.1954 (BRI); Kroombit Tops National Park, W section, *E.J.Thompson BIL121 & G.P.Turpin*, 30.viii.1995 (BRI, MEL).

Flowering period: Flowers at various times. Mature fruit recorded for March.

Distribution and habitat: Occurs in south-eastern Queensland, between 24°S and 26°S (Fig. 5). Grows in brown or red loamy soils in woodland or forest.

Notes: A rare or perhaps undercollected species characterised by small flowers and short, oblong pods that have a relatively low length:width ratio. In terms of petal markings, the flowers are similar to those of *G. medicaginea* and *G. stenocarpa*. In the absence of flowers or fruit, *G. parviflora* can be distinguished from the other two species occurring in Queensland by its persistent stipules (caducous in *G. lotifolia*) or by its near-glabrous branchlets (current season branchlets moderately hairy in *G. macrocarpa*). Stipules of *G. parviflora* are longer and less hairy than those of *G. macrocarpa*. A portion of the holotype and pods from the isotype are shown in figure 7.

Figure 7. *Goodia porviflora*. a. portion of holotype; b. portion of isotype (a. & b. *A.R.Beon 10159* MEL, two sheets). Scale bars: a = 10 mm, b = 5 mm.

Excluded names (see Ross 1997 for further details)

Goodia polysperma A.DC., *Rapp. Pl. Rar. Geneve* 2(2): 13 (1824).

Referable to the South African species *Argyrolobium tomentosum* (Andrews) Druce.

Goodia simplicifolia Spreng., *Syst. Veg.* edn 16, 4: 267 (1827).

Referable to *Hovea elliptica* (Sm.) DC.

Goodia retusa Sweet, *Hort. Brit.* 110 (1826).

A nomen nudum of uncertain application.

?***Goodia medicaginea*** Jacques, *J. Soc. Imp. Centr. Hort.* 10: 116 (1864), *nom. illeg.*

An illegitimate name of uncertain application. Ross (1997) indicates that it is uncertain whether Jacques was intending to describe a new species in this case.

Acknowledgments

I am grateful to the Royal Botanic Gardens, Melbourne, particularly Alison Vaughan and the collections staff for their assistance with mapping and loan processing, and to the directors of AD, BRI, CANB, HO, MEL, NSW, PERTH and NE for making their collections available for study. Thanks also to Lachlan Copeland for his assistance with collections and images. This study was funded by a grant from the Australian Biological Resources Study (ABRS Grant no. 207-01), which is a program within the Department of Sustainability, Environment, Water, Population and Communities.

References

Bentham, G. (1864). '*Goadia*' In G.Bentham, *Flora Australiensis*. **Vol. 2**., pp. 176–177. Lovell Reeve & Co.: London.

Crisp, M.D. and Weston, P.H. (1987). 'Cladistic and legume systematics, with an analysis of the Bossiaeeae, Brongniartieae and Mirbelieae'. In C.H.Stirton (ed.), *Advances in Legume Systematics*, **Vol. 3**, pp. 65–130. Royal Botanic Gardens, Kew: London.

Crisp, M.D. and Cook, L.G. (2003). 'Phylogeny and embryo sac evolution in the endemic Australasian papilionoid tribes Mirbelieae and Bossiaeeae'. In B.Klitgaard and A.Bruneau (eds), *Advances in Legume Systematics*, **Vol. 10**, pp. 253–268. Royal Botanic Gardens: Kew.

Ross, J.H. (1997). Notes on *Gaodia* (Fabaceae, Bossiaeeae). *Muelleria* **10**, 1–11.

Thompson, I.R. (2011). A revision of *Muelleranthus*, *Aenictophyton* and *Ptychasema* (Fabaceae: Bossiaeeae). *Muelleria* **29**, 173–189.

Weber, J.Z. (1986). *Goodia*, In J.P.Jessop & H.R.Toelken (eds), Flora of South Australia, 4th edn, **Vol. 2**, pp. 691–692. Government Printer: Adelaide.

A revision of *Platylobium* (Fabaceae: Bossiaeeae)

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Abstract

A revision of the Australian-endemic genus *Platylobium* Sm. (Fabaceae: Bossiaeeae) is presented. Four new species are described: *P. rotundum* I.Thomps., *P. infecundum* I.Thomps., *P. montanum* I.Thomps., and *P. reflexum* I.Thomps., all segregated from *P. formosum* Sm. *Platylobium parviflorum* Sm. is returned to species rank. A new subspecies, *P. montanum* subsp. *prostratum* I.Thomps., is also described. Keys to species and distribution maps are presented.

Keywords: morphology, taxonomy, biodiversity, flowering plants, peas, legumes.

Muelleria 29(2): 154-172 (2011)

Introduction

Platylobium Sm. is a small genus of shrubs in the Australian-endemic tribe Bossiaeeae (Fabaceae). It is distinguished from the other six genera in the tribe by the combination of distichous phyllotaxy, unifoliolate leaves with a relatively large leaflet, several scales subtending single-flowered inflorescences, massively expanded and rounded upper calyx-lobes, and flat, thinly winged pods. *Platylobium* occurs in areas of moderate to high rainfall in south-eastern Australia with the greatest diversity in Victoria. It is closely related to the much larger genus *Bossiaea* Vent. which possesses many of the features described above, but does not have pods with a thinly winged upper suture. The other genera in the tribe, *Goodia* Salisb., *Paragoodia* I.Thomps. (Thompson 2011), *Muelleranthus* Hutch., *Ptychosema* Benth., and *Aenictophyton* A.T.Lee, all differ in most respects to the combination of features given above.

Taxonomic History: The genus and two species, *Platylobium formosum* Sm. and *P. parviflorum* Sm., were described in 1793, followed by *P. triangulare* R.Br. in 1812 and *P. obtusangulum* Hook. in 1833. The number of species recognised was reduced to three when Bentham (1864) treated *P. parviflorum* as a variety of *P. formosum*. *Platylobium alternifolium* F.Muell. was described in 1883. Over the next 100 years the only taxonomic change was a change of status of *P. formosum* var. *parviflorum* (Sm.) Benth. to subspecies rank. More recently, Ross (1983) produced a revision of the genus in which no changes were made except for the loss of status of *P. parviflorum*. Thus, as this study commenced, four species of *Platylobium* were recognised in Australia. In New South Wales, *P. formosum* subsp. *parviflorum* (Sm.) A.T.Lee continued to be recognised, most recently by James (2002).

Methods

This morphological study utilised herbarium material predominantly, which was examined with the aid of a dissecting microscope. Pressed flowers were reconstituted using hot soapy water to facilitate examination. Specimens from AD, BRI, CANB, HO, MEL and NSW were examined. Field examination and collection at numerous locations in Victoria and New South Wales also contributed to the author's

understanding of the genus. All images presented were taken by the author using a Canon PowerShot A2000 IS digital camera.

Results

The results of this morphological study are presented in the taxonomic section below. In summary, the pattern of morphological variation identified calls for the recognition of four new species and one new subspecies, as well as the return of *P. parviflorum* to the rank of species. All new taxa are segregated from *P. formosum* as circumscribed by Ross (1983). The circumscriptions of *P. triangulare*, *P. obtusangulum* and *P. alternifolium* are unchanged.

The more important taxonomically useful characters recognised for *Platylobium* in this study include: habit; fertility; distribution and density of indumentum; phyllotaxis; length of petiole and the distinctness of the petiole-petiolule articulation; leaflet shape; length of pedicels; length, shape, colour, texture and recurvature of bracteoles; length of pod-stipe; and width of wings of pods.

Taxonomy

***Platylobium* Sm., *Spec. Bot. New Holland* 1: 17, t. 6 (1793)**

***Type*: *P. formosum* Sm.**

Shrubs or subshrubs, erect, climbing, sprawling or prostrate, to c. 2 m high, sometimes slightly glaucous. *Indumentum* of simple hairs scattered on branches, leaves, pedicels, calyces and pods, and less commonly on stipules, scales, bracts and bracteoles; branches and leaves often glabrescent; hairs 0.5–1.5 mm long, spreading or antrorse-appressed. *Stipules* triangular-ovate to triangular-lanceolate, often becoming deflexed, scaly, striate, brown, gradually eroding; scales developed instead of leaves and stipules at and towards the base of floral and vegetative axes. *Leaves* distichous, opposite or alternate, unifoliolate, inserted on prominent branch flanges; petiole pulvinate; petiole-petiolule articulation conspicuous or indistinct; petiolule short, pulvinate; lamina triangular, ovate or orbicular, sometimes with acute to obtuse baso-lateral angles or lobes which are often pungent, coriaceous, with conspicuous reticulate venation, commonly glabrescent but with hair-bases commonly persisting as minute tubercles; base deeply cordate to broad-cuneate; apex rounded to acute, apiculate, with apiculum sometimes pungent. *Inflorescences* arising from axils of short lateral branches or towards termini of longer branches, with 1–4 inflorescences per axil; each inflorescence comprising 1, or very rarely 2, pedicellate flowers subtended by 4–16 scales; scales generally crowded, brown, chartaceous, sometimes striate, ciliate marginally, increasing in length successively; bract and bracteoles similar in appearance to scales, persistent; bracteoles opposite or sub-opposite, ovate to lanceolate, mostly inserted strongly distally on pedicel; receptacle c. 0.5 mm long. *Calyx* 5–12 mm long, with tube 1.5–3 mm long; upper lobes much longer than tube, much broader and longer than lower lobes, almost free, dilating distally, with apex rounded; lateral angle not or hardly evident; lower lobes triangular; petals clawed, with standard claw longest; standard slightly longer than wings and keel, with limb oblate, deeply emarginate; adaxial surface yellow or rarely orange with a red or pinkish flare around a yellow, red-flecked throat, abaxially purple-brown with variable bands of yellow at sides; wings obovate, straight to slightly downcurved, slightly longer than and mostly slightly narrower than keel, pure yellow or variously marked red; keel with apex rounded, with petals free, white basally, dark red towards apex; anthers uniform in size, all dorsifixed; ovary 3–8-ovulate; stigma capitate. *Pods* stipitate; body oblong, elliptic or rhomboidal, strongly compressed, with upper suture forming a thin wing; valves chartaceous, glabrous or sparsely to densely hairy, becoming revolute post-dehiscence. *Seeds* reniform or ellipsoid, ±plump, brown or black, sometimes mottled; aril one-third to one half of length of seed, with base elliptic, open at one end, and with a large, arching vertical lobe arising from the closed end.

***Notes on morphology*: LEAVES**: Figure 1a shows some of the more significant aspects of variation seen in the shape of the lamina of the terminal leaflet. There is moderate variation in shape within each species, so these examples, although typical, are a guide only for the species shown. Figure 5 shows a further variation, the near-circular lamina commonly seen in *P. rotundum*.

PETIOLE-PETIOLULE ARTICULATION: Figures 1b and 1c shows an important aspect of leaf morphology

in *Platylobium* which can be used to distinguish *P. triangulare*, *P. formosum* and *P. parviflorum*, from the other six species in the genus. In these three species there is no clear articulation evident between petiole and petiolule. Instead, an apparently single pulvinate structure curves between branch and leaflet-lamina, and so the leaf appears to be simple rather than unifoliolate. In the other six species, in contrast, there is a distinct articulation which is detectable by either a ridge, an obtuse angle, or by the different thicknesses of the petiole and the petiolule. Often two or all of these elements contribute together. In *P. reflexum* and *P. obtusangulum*, which have short petioles, inspection at low magnification will be necessary to identify a ridge or angularity. Similar variation in the morphology of the petiole-petiolule articulation occurs in the closely related genus *Bossiaea*, and in this genus too it can aid in distinguishing species.

SCALES: Clusters of several strongly overlapping bud scales (hereafter scales) persist at or near the base of both vegetative and inflorescence branches. Scales are formed by the fusion of a pair of stipules. There is a progressive increase in the size of the scales from the base of the axis. For vegetative axes, there are commonly

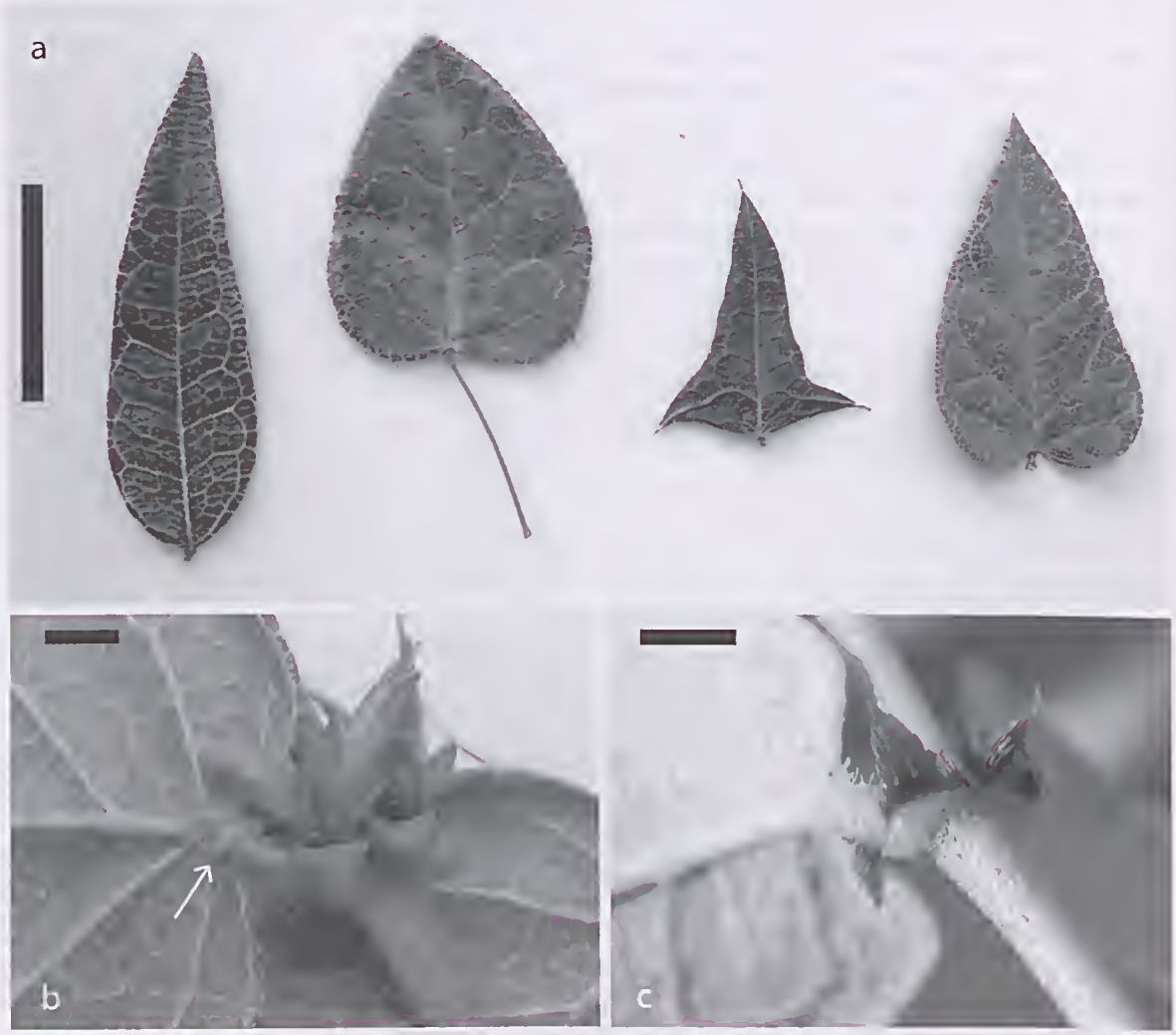

Figure 1. Leaves. a. Leaflet-lamina, examples. From l to r: *P. parviflorum*, *P. infecundum*, *P. obtusangulum*, *P. montanum* (*IRT 1214* MEL, *IRT 1104* MEL, *IRT 1141* MEL, and *IRT 1216* MEL respectively). b. & c. Petiole-petiolule articulation. b. *P. reflexum*, ridge indicating articulation indicated by arrow. Insertion of petiole onto branch is hidden by stipule (*IRT s.n., Aug. 2009*, MEL), c. *P. parviflorum*, articulation obscure (*IRT 1137* MEL). IRT = Ian R. Thompson. Scale bars: a–b = 10 mm, c–d = 2 mm.

a few to several alternately arranged scales inserted along the axis, distal to the overlapping cluster of scales, before the first leaf is produced at a node, and bifid scales (partly fused stipules), occasionally occur in this region. Sometimes the majority of scales are scattered along an axis rather than crowded basally.

BRACTS AND BRACTEOLES: Bracts and bracteoles are more or less identical to scales morphologically but are slightly larger. In fresh specimens, notably in *P. montanum*, they are sometimes still slightly green and glaucous at anthesis. In this paper, unlike in Ross (1983), the pedicel is defined as extending from the insertion point of the distalmost scale to the receptacle. The bract is inserted at the base of the pedicel and therefore is strongly overlapped by at least the distalmost scale. In descriptions below, the bract and scales together is called the scale-bract cluster. Bracteoles are mostly inserted distally on the pedicel and are therefore generally clearly separated from the cluster. In *P. obtusangulum* the separation is less and the bract overlaps the bracteoles. Examples of scale, bract and bracteole arrangements are shown in figures 2 and 4. Usually the axis on which scales are inserted is very short; however, in *P. alternifolium*, and occasionally in other species, notably *P. montanum*, the branch is more elongate and scales more widely spaced.

FLOWERS: Figure 2c and 2d show abaxial and adaxial views of the standard petal. Although the

Key to species of *Platylobium*

1 Leaves all alternate 2

1: At least some leaves opposite 3

2 Calyx glabrous externally (margins ciliolate); pedicels (bract to receptacle) 3–6 mm long; leaflet-lamina ovate with base mostly cordate ..... ***9. P. alternifolium***

2: Calyx hairy externally; pedicels mostly 20–50 mm long; leaflet-lamina commonly c. broad-ovate to c. circular, with base mostly rounded ..... ***8. P. rotundum***

3 Petiole-petiolule articulation obscure in all or most leaves (ie. leaves appear simple) 4

3: Petiole-petiolule articulation distinct (geniculate and/or with ridge development) in all or most leaves (ie leaves are clearly unifoliolate) 6

4 Leaves somewhat triangular, and at least some with baso-lateral points; standard and wings orange-yellow ..... ***2. P. triangulare***

4: Leaves ovate to lanceolate, without baso-lateral points; standard and wings bright yellow 5

5 Calyx (7.5–)8–12 mm long; bracteoles < half of length of calyx; scales, bracts and bracteoles ±evenly hairy abaxially; pod-wings 3–5.5 mm wide ..... ***3. P. formosum***

5: Calyx 5–8 mm long; bracteoles > half of length of calyx; scales and bract glabrous abaxially or with only a few midline hairs (bracteoles glabrous or hairy); pod-wings 1.5–3.5 mm wide ..... ***4. P. parviflorum***

6 Pedicel not exceeding bract; calyx 8–12 mm long; stipe of pods 1–2 mm long; leaves often with acute to obtuse baso-lateral angles and these often pungent ..... ***1. P. obtusangulum***

6: Pedicel generally clearly exceeding bract, or if not then calyx < 7 mm long; stipe of pods 5–15 mm long; leaves rounded baso-laterally 7

7 Bracteoles convex throughout, not becoming reflexed (or slightly reflexed at tip only), smooth, or slightly striate, brown to reddish-brown ..... ***5. P. montanum***

7: Bracteoles nearly flat in distal half, mostly becoming reflexed, orange-brown, markedly striate 8

8 Petioles predominantly < 5 mm long; plants becoming weakly erect, to c. 1 m high (or higher if supported by vegetation); plants generally fertile ..... ***6. P. reflexum***

8: Petioles frequently 5–20 mm long; plants prostrate; plants generally infertile ..... ***7. P. infecundum***

Figure 2. a. *P. reflexum*, cluster of inflorescences (*IRT 1100* MEL), b. *P. formosum*, flowering branch, showing hairy scales (*IRT 1201* MEL), c. *P. obtusangulum*, flower shortly before opening (*IRT 1094* MEL), d. *P. infecundum*, flower (*IRT 1104* MEL), e. *P. formosum*, pod, persistent calyx and bracteoles (*IRT 1201* MEL), f. *P. montanum* subsp. *montanum*, fruit (*IRT 1216* MEL), g. *P. parviflorum*, inside of pod valve after dehiscence (*IRT 1214* MEL), h. *P. reflexum*, seed (*IRT 1132* MEL). IRT = Ian R. Thompson. Scale bars: a, c-d = 5 mm, b = 2 mm, e–g = 10 mm, h. Seed is 2.8 mm long.

images are from different species, the presence of extensive marking of the abaxial surface occurs in all species. The red to purplish (drying dark grey often) markings sometimes do not extend all the way to the lateral margins of the standard leaving a yellow band on each side. The markings are perhaps least extensive in *P. parviflorum* and *P. formosum*.

A distinctive feature of *Platylobium* is the large size difference between upper and lower lobes of the calyx. This is demonstrated in figures 2e and 2f which show fruit with a persistent calyx.

Detailed illustrations of *Platylobium* are presented in Ross (1983). Figures 2 and 4 in this paper show useful illustrations of *P. alternifolium*, *P. obtusangulum* and *P. triangulare*, while Figure 6 shows some of the variation in *P. formosum sensu* Ross (1983). Based on the taxonomic changes made herein, the new names for the elements in Figure 6 are as follows: a. & b. shows *P. montanum* subsp. *montanum*, c. & d. shows *P. parviflorum*, and e. shows *P. montanum* subsp. *prostratum*.

1. *Platylobium obtusangulum* Hook., in W.J.Hooker (ed.) *Curtis's Bot. Mag.* 60: t. 3258 (1833)

Type: Iconotype t. 3258, *loc. cit.*

P. macrocalyx Meisn., *in* J.G.C.Lehmann, *Pl. Preiss.* 1: 80 (1844). *Type*: Victoria. Port Phillip, *C. Latrobe*, 1842; lectotype: NEU, *fide* J.H.Ross, *Muelleria* 5(2): 134 (1983).

P. obtusangulum var. *spinulosum* J.H.Willis, *Muelleria* 1: 126 (1967). *Type*: Victoria. On Aireys Inlet to Wensleydale Road, ± 3.2 km N of Forestry Tower at Peter's Hill, *M.Allender*, 12.xi.1961; holotype: MEL1522466.

[*P. triangulare auct. non* R.Br. (1812): Sims, *Bot. Mag.* t. 1508 (1812); J.D.Hooker, *Fl.Tasman.* 1: 96 (1856)]

Erect to sprawling shrubs, to c. 1 m high. *Stipules* 2–3 mm long, 1–1.5 mm wide. *Leaves* opposite; petiole 0.5–2(–4) mm long; petiole-petiolule articulation mostly distinct; lamina ovate to narrow-ovate, c. triangular, or trilobate, occasionally c. circular, rarely lanceolate, 10–30 mm long, 5–25 mm wide with l:w ratio mostly 1–2, rarely to c. 5; baso-lateral angles or lobes common, often with pungent points; base broad-cuneate, truncate, cordate, or sagittate; margin flat to recurved; apex acute to very acute with a pungent apiculum 0.5–3 mm long; upper surface often tuberculate, secondary veins ± spreading at widest part of leaf, often arching backwards; lower surface often with a persistent pubescence; midrib to c. 0.5 mm wide. *Inflorescences* 1–3 per axil; scales 6–14, glabrous or with hairs in midline and/or near apex; scale-bract cluster 6–10 mm long; bract 4–8 mm long; pedicel 3–8 mm long; bracteoles inserted immediately below receptacle, 5–10 mm long, 3–5 mm wide, strongly convex throughout, not becoming reflexed, weakly striate, glabrous or with hairs medially and distally, orange-brown. *Calyx* 8–12 mm long, with a moderately dense indumentum of loosely appressed hairs; upper lobes 6–10 mm long, 4–8 mm wide, with sinus 5–8 mm deep, lower lobes 2–3 mm long; standard 10–14 mm long, 12–18 mm wide, with claw c. 3 mm long; abaxial surface red grading to purple-brown ±throughout; wings 9–12 mm long, 3–3.5 mm wide, red proximally or almost throughout; keel 8–11 mm long, c. 4 mm wide; style 4–6 mm long. *Pods*: stipe c. 1 mm long; body 10–25 mm long, 10–15 mm wide, including wing 2–4 mm wide, mid-brown, commonly 4 or more-seeded; sutures hairy, valves glabrous or with scattered hairs, hairs longer in zone overlying seed; funicles c. 1 mm long. *Seeds* 2.5–3 mm long, 1.8–2 mm wide, brown; aril 1.5–2 mm long, c. 1 mm high, with base 1–1.5 mm long; lobe slightly overhanging base.

Selected specimens of over 400 examined: **SOUTH AUSTRALIA**: E of Mt Lofty summit, *R.Bates 658*, iv.1980 (AD); Head of Sou' West R., c. 75 km WSW of Kingscote, *J.B.Cleland*, 27.xi.1924 (AD); Crompton's Scrub, c. 15 km WSW of Victor Harbour, *D.Hunt 3330* (AD); Lenswood Research Centre, c. 20 km ENE of Adelaide, *H. van Dam 232*, 28.ix.1969 (AD). **VICTORIA**: Beside Western Hwy, S of Mt Langi Ghiran, *I.C.Clarke 1985*, 11.x.1989 (CANB, MEL1582873, NSW); Halls Gap to Roses Gap Rd, *T.Henshall*, 5.xi.1967 (MEL721797); Victoria Valley, near junction of Syphon Rd and Serra Rd, *M.G.Corrick 10254*, 1.xi.1987 (CANB, MEL1575689); Yanakie-Black Swamp Rd junction, *A.Worz*, 29.x.1992 (MEL2070995); Bordman's Track, c. 3 km W of Mt Anakie, *R.V.Smith 59/235*, 25.ix.1959 (AD, MEL1534389); c. 1 km from Fernbank Rd in railway reserve, S of railway line, *R.J.Fletcher 301*, 4.xi.1994 (MEL2023586); Rockbeare Park, Ivanhoe, *R.V.Smith 87/2*, 13.xi.1987 (AD, CANB, HO, MEL2034294, NSW); c. 7 km N of Anglesea, along Gum Flat Rd, *H.I.Aston 354*, 15.x.1959 (MEL721799). **TASMANIA**: E side of Rocky Cape National Park, *A.C.Rozefelds 1869*, 28.ix.2000 (HO); Near Freestone Hill, c. 20 km N of Swansea, *A.M.Buchanan 4808*, 11.xii.1984 (HO); W side of Chinese Ck, Schouten Island, *A.C.Rozefelds 1924*, 14.xi.2000 (HO); Cambridge, *A.V.Giblin*, 23.x.1929 (HO); Launceston, *Hannaford 821*, x.1863 (MEL572082).

Flowering period: Flowers spring.

Distribution and habitat: Occurs in far south-eastern South Australia, southern Victoria, and Tasmania (Fig. 3). A specimen with a label indicating Darling Range, Western Australia (*Lucas* NSW 42987) is *P. obtusangulum*; however, the locality is highly unlikely and the specimen is therefore deemed incorrectly labelled. Grows in various soils in forest and heathland.

Notes: *Platylobium obtusangulum* shows considerable variation in leaf morphology, but is relatively uniform in other characters. When sterile, it can be distinguished from *P. triangulare*, a species with similar angular leaves, by examining the petiole-petiolule articulation. In *P. obtusangulum* the petiole is distinctly ridged at the articulation and the articulation is often geniculate (as in figure 1b showing *P. reflexum* but with a shorter petiole); in *P. triangulare* the articulation is not evident, ie. the leaves appear to be simple rather than unifoliolate (as in figure 1c showing *P. parviflorum*).

One extreme variant with leaves bearing additional lobes and spines was described by Willis (1967) as *P. obtusangulum* var. *spinulosum* Willis based on plants collected from near Anglesea in south-central Victoria. This variety was not recognised by Ross (1983) and is not recognised here. Specimens with the same leaf morphology have been recorded in recent decades from the Southern Lofty region of South Australia, e.g. Newland Head Conservation Park (*R.Taylor s.n.* AD) and Mt Lofty summit (*R.Bates 658* AD), and from Melbourne (*P.Raufer s.n.* MEL) and Gippsland (*R.Fletcher 301* MEL) in southern Victoria. In all cases, the typical leaf forms of *P. obtusangulum* occur in the same area.

Hybrids: Hybridisation between *P. obtusangulum* and *P. triangulare* has been recorded from Wilsons Promontory (*M.G.Corrick 7069* MEL & *M.G.Corrick 7072* AD, MEL, NSW) and from Rocky Cape National Park, Tasmania (*M.Wapstra s.n.*, 10.xii.2008 MEL).

2. *Platylobium triangulare* R.Br., in W.T.Aiton, *Hortus Kew*. edn 2, 4: 266 (1812)

Type: Tasmania. King Island, *R.Brown*, 23.iv.1802; lectotype: BM, *fide* J.H.Ross, *Muelleria* 5(2): 131 (1983), image MEL.

P. murrayanum Hook., *in* W.J.Hooker (ed.), *Curtis's Bot. Mag.* 60: t. 3259 (1833). *Type*: Iconotype, *loc. cit.* [Drawn from a cultivated plant grown from seed collected in Tasmania.]

Weakly erect to sprawling shrubs, to c. 0.5 m high. *Stipules* 1–2 mm long, c. 1 mm wide. *Leaves* opposite; petiole 0.5–1 mm long; petiole-petiolule articulation generally obscure; lamina triangular or triangular-ovate, 10–30 mm long, 7–22 mm wide, with l:w ratio mostly 1–2; acute baso-lateral angles developed on all or a proportion of leaves, angles often with pungent points; base truncate, cordate or sometimes sagittate; margin recurved; apex acute with a pungent apiculum 0.5–2.5 mm long; upper surface sometimes tuberculate, secondary veins c. spreading at widest part of leaf, sometimes arching back; lower surface usually glabrescent; midrib to c. 0.4 mm wide. *Inflorescences* 1 or 2 per axil; scales 6–8, glabrous; scale-bract cluster 2–4 mm long; bract 2–2.5 mm long; pedicel 5–12 mm long; bracteoles inserted 1–3 mm below receptacle, 1.5–3 mm long, 1–2 mm wide, flat, commonly reflexed, distinctly striate, glabrous or with a few midline hairs, reddish. *Calyx* 7–11 mm long, with a scattered indumentum of loosely appressed hairs; upper lobes 5–9 mm long, 4–7 mm wide; lower lobes 1.5–2.5 mm long; standard 10–12 mm long, 12–18 mm wide, with claw 3–4 mm long, adaxial surface orange with flare pinkish-red; abaxial surface purple-brown ±throughout; wings 9–12 mm long, 4–5 mm wide, with pinkish-red markings proximally; keel 8–10 mm long, 4–5 mm wide; style 3–4 mm long. *Pods*: stipe 2–7 mm long; body (15–)20–30 mm long, 11–18 mm wide including wing 2–3 mm wide, light brown, up to 8-seeded; sutures hairy, valves glabrous; funicles c. 1 mm long. *Seeds* c. 3 mm long, c. 2 mm wide, brown; aril 1.5 mm long, 1 mm high, with base 1.3 mm long; lobe overhanging base.

Selected specimens of c. 40 examined: **VICTORIA**: Behind beach, Waterloo Bay, *M.G.Corrick 7078*, 6.xi.1980 (MEL576042); Heath Road, just past Pipeclay ext., Lower Glenelg National Park, *R.J.Fletcher 190*, 17.ix.1993 .(MEL2018043); Orford, *H.B.Williamson*, x.1899 (MEL584533); Tullich Rd, c. 12 km E of Casterton, *M.G.Corrick 8483*, 1.xi.1982 (MEL641465); Along the main Portland–Nelson Rd, c. 5 km SE of Gorae West, *H.I.Aston 726*, 22.x.1960 (MEL570858); McCraes Rd, W of Portland, *C.& D.Woolcock 1395*, 10.xii.1983 (MEL654694); Near Mt Richmond, 29 km from Portland towards Nelson, *M.E.Phillips 266*, 28.x.1971 (CANB). **TASMANIA**: Beach end N of Bicheno, *H.D.Gordon*,

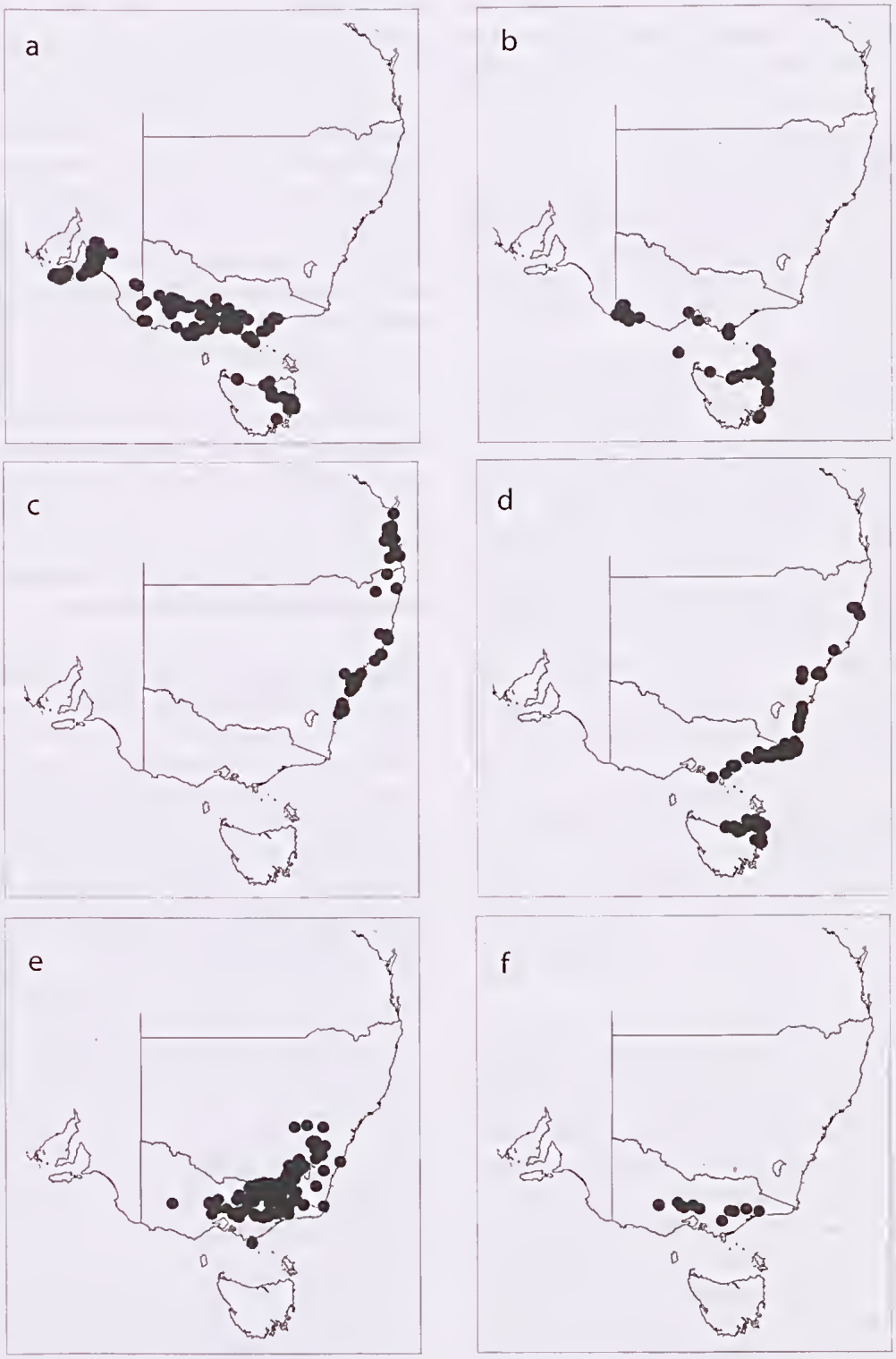

Figure 3. Distributions of a. *Platylobium obtusangulum*, b. *P. triangulare*, c. *P. formosum*, d. *P. parviflorum*, e. *P. montanum* subsp. *montanum* and f. *P. montanum* subsp. *prostratum*.

18.xi.1942 (HO); Cape Barren Island, *P.Cullen*, xii.1989 (HO); St Helens, *W.M.Curtis*, x.1945 (HO); Mt Cameron, *A.Moscal 377B*, 23.x.1983 (HO); Bridport, *P.Collier 2647*, 29.viii.1986 (HO); Mt Killiecrankie, Furneaux Group, *J.S.Whinroy 2587*, 23.ix.1978 (CAN8).

Flowering period: Flowers spring.

Distribution and habitat: Occurs in far south-western Victoria, Wilsons Promontory in south-central Victoria, and in northern and eastern Tasmania, including King Island and the Furneaux Group of islands in Bass Strait (Fig. 3). Grows in heath, woodland and forest, commonly in sandy soils.

Notes: *Platylobium triangulare* is readily distinguished by its floral features, and from most other species by its leaf shape. In the absence of reproductive structures it can be distinguished from *P. obtusangulum* q.v., which has similarly shaped leaflet-laminas by examination of the petiole. As discussed in the notes under the generic description, in *P. triangulare* the petiole-petiolule articulation is obscure (see Figure 1c which shows *P. parviflorum*). In *P. obtusangulum* a ridge and sometimes the formation of an angle indicates the position of articulation.

Platylobium triangulare hybridises with *P. obtusangulum* q.v.

3. *Platylobium formosum* Sm., *Spec. Bot. New Holland* 1:18 (1793)

P. formosum var. *typicum* Domin., *Biblioth. Bot.* 89: 728 (1925).

Type: New South Wales. Location unknown, *J.White*, 1793 [sheet 1188.1]; lectotype: LINN, *fide* J.H.Ross, *Muelleria* 5(2): 136 (1983).

Erect shrubs, to c. 1.5 m high. *Stipules* 2–5 mm long, 1–1.5 mm wide. *Leaves* opposite; petiole 1.5–2.5 mm long; petiole-petiolule articulation generally obscure; lamina ovate to narrow-ovate or elliptic, 30–50 mm long, 15–40 mm wide, with l:w ratio mostly 1.2–2.2; baso-lateral points not developed; base rounded to cordate, uncommonly cuneate; margin recurved to slightly revolute; apex subacute or acute, with apiculum to c. 1 mm long, mostly withered, brittle; upper surface mostly not or only sparingly tuberculate except on veins, secondary veins angled gently forwards (15–30°) at widest part of leaf; lower surface glabrescent; midrib c. 0.6 mm wide. *Inflorescences* 1 or less often 2 per axil; scales 4–6, hairy all over; scale-bract cluster 3–4 mm long; bract 2–3 mm long; pedicel 3–12 mm long; bracteoles inserted immediately below receptacle, 3–4 mm long, 2–3 mm wide, ± flat in distal half, often becoming reflexed, distinctly striate, hairy all over, red-brown. *Calyx* (7.5–)8–12 mm long, with a sparse to moderately dense indumentum of loosely appressed hairs; upper lobes 5.5–9 mm long, 4–5 mm wide; lower lobes 2–3 mm long; standard 15–20 mm long, 18–25 mm wide, with claw 3–4 mm long; abaxial surface purple-brown with yellow bands at sides; wings 12–14 mm long, 4.5–6 mm wide, yellow throughout; keel 9–13 mm long, 5–7 mm wide, style 4–5 mm long. *Pods*: stipe 5–10 mm long; body 25–45 mm long, 15–20 mm wide including wing 3–5.5 mm wide, mostly mid-brown, mostly 4–8-seeded; sutures hairy, valves with hairs restricted to zone overlying seeds; funicles 1.5–2 mm long. *Seeds* 3–3.5 mm long, c. 2 mm wide, mid or dark brown; aril 1.5–2 mm long, c. 1 mm high, with base 1.5–1.8 mm long; lobe very slightly overhanging base.

Selected specimens of c. 80 examined: **QUEENSLAND**: 1.5 km NW of Caloundra, *J.H.Ross 313B*, 24.viii.1986 (AD, BRI, CAN8, HO, MEL, NSW); Oakey Creek Rd, SF 1239, NW of Mapleton, *A.R.Bean 10735*, 13.ix.1996 (BRI); Prout Rd, Burbank, *G.Leiper*, ix.2001 (BRI); Mt Cooroora, 1 km SW of Pomona, *I.R.Telford 3426*, 2.x.1973 (CAN8, MEL, NSW). **NEW SOUTH WALES**: Cowan Quarry, near Cowan, *G.Corsini 62*, 11.xii.1996 (CAN8); 1.7 km W of Tomerong, on Turpentine Rd, towards Sassafras, *T.R.Lolly and B.Lofoy 471*, 7.xii.1994 (CANB); NE border of Crowdy Bay National Park, Tahlee, Port Stephens, *E.F.Constable s.n.*, 23.x.1956 (NSW); Range Road, Tabbimoble SF, N of Grafton, *A.R.Bean 17940*, 15.ix.2001 (BRI); Princes Hwy, S side of Currumbene Creek, 20 m W of bridge, *F.E.Dovies 142, B.Hodlow & R.Hart*, 3.xii.1986 (CAN8, MEL); 1.8 km along Forest Rd towards Currawong. Turnoff is 8 km S of Nowra, *P.C.Jobson 377B*, 18.ix.1995 (MEL); E side of Myall Lakes Rd, 2.6 km S of Seal Rocks, *P.C.Jobson 5577 & C.C.Simpson*, 14.ix.1998 (MEL, NSW); 1.5 km N of Colo Heights, *M.Tindole*, 28.xi.1959 (NSW); Manly-Warringah War Memorial Park, Sydney, *D.Gibbons*, 20.x.1986 (NSW); Jervis Bay (Australian Commonwealth Territory), *E.Gaubo 1362*, 16.ix.1951 (CANB, NSW).

Flowering period: Flowers late winter to spring.

Distribution and habitat: Occurs in near coastal areas of south-eastern Queensland, south of Maryborough, and in New South Wales where it extends from the far north as far south as Jervis Bay (Fig. 3). Grows on sandstone in forest and heathland.

Notes: Rather than a polymorphic species as previously described, *Platylobium formosum* as newly circumscribed, is relatively uniform morphologically, and is characterised by large flowers, in particular a large calyx, hairy scales, bracts and bracteoles, and widely-winged pods. From *P. parviflorum*, probably its closest relative, it further differs in having leaves, on average, with a lower length:width ratio. Pods usually also differ in having a band of long hairs on the valves overlying the seeds. This pattern is rare in *P. parviflorum*. Scale and pod morphology are shown in figures 2b & e respectively. One duplicate of a collection from Cape Howe in far south-eastern New South Wales (*Constable 3277* MEL) is *P. formosum*. However, the other collection held at NSW is of *P. parviflorum*, the species you would expect to find at Cape Howe. The MEL specimen is considered highly unlikely to be from Cape Howe, and the record is not included here in the distribution map for *P. formosum*. The two species are probably sympatric at several places along the New South Wales coast, but there is no evidence of hybridisation except perhaps for a collection from Kelly's Falls near Helensburgh on the Central Coast (*Coveny 11272* NSW, MEL).

4. *Platylobium parviflorum* Sm., *Spec. Bot. New Holland* 1: 17, t.6 (1793)

P. formosum var. *parviflorum* (Sm.) Benth., *Fl. Austral.* 2: 154 (1864); *P. formosum* subsp. *parviflorum* (Sm.) A.T.Lee, *Contrib. New South Wales Natl. Herb.* 4: 96 (1970).

Type: New South Wales. Location unknown, *J.White*, 1793 [sheet 1188.3, no. 1]; lectotype: LINN, *fide* J.H.Ross, *Muelleria* 5(2): 136 (1983) *n.v.*, image seen MEL.

P. ovatum Sieber ex DC., *Prodr.* 2: 116 (1825), *nom. illeg. non* Andr. (1802). *Type*: New South Wales. Location unknown, *F.Sieber 374*, date unknown; holotype: G; isotype: CANB7801643, MEL571654, MEL571657, NSW564484.

Erect shrubs, to c. 2 m high. *Stipules* 3–6 mm long, 1–2.5 mm wide. *Leaves* opposite, or cataphylls and near basal leaves sometimes alternate; petiole mostly 1–2 mm long, occasionally to 4 mm long in lower leaves; petiole-petiolule articulation generally obscure, or occasionally proximal leaves have longer petioles and then articulation distinct; lamina narrow-ovate to lanceolate or narrow-elliptic, 20–60 mm long, 10–30 mm wide, with l:w ratio 1.5–4(–6); baso-lateral points not developed; base cuneate to broadly rounded, rarely slightly cordate; margin nearly flat to recurved; apex acute to narrowly acute with apiculum to c. 2 mm long, sometimes spine-like but non-pungent; upper surface sometimes minutely tuberculate, secondary veins angled forward at 10–30(–40)° at widest part of leaf; lower surface glabrescent; midrib c. 0.5 mm wide. *Inflorescences* 1–3 per axil; scales 8–12, glabrous or with a small patch of hairs; scale-bract cluster 3–5 mm long; bract 2.5–3.5 mm long; pedicel 5–15(–20) mm long; bracteoles inserted 1–2 mm below receptacle, 2.5–6 mm long, 1.5–3 mm wide, convex, not reflexing, mostly distinctly striate, glabrous or with a medial band of hairs or rarely hairy over most of surface, reddish-brown. *Calyx* 5–7 mm long, with a scattered indumentum of appressed hairs; upper lobes 3–5 mm long, 2.8–4 mm wide; lower lobes 1–2 mm long; standard 10–12 mm long, c. 15 mm wide, with claw c. 3 mm long; abaxial surface purple-brown with narrow to broad yellow zones at sides; wings 9–12 mm long, 4–5 mm wide, entirely or mostly yellow; keel 8–11 mm long, 4–5 mm wide; style 3–5 mm long. *Pods*: stipe 4–12 mm long; body 15–30 mm long, 12–14 mm wide including wing 1.2–3(–3.5) mm wide, mid-brown, mostly 4–8-seeded; sutures hairy; valves glabrous or hairy all over, or rarely with hairs overlying seeds only; funicles 1–1.5 mm long. *Seeds* 2.5–3 mm long, 1.6–2 mm wide, mid to dark brown, occasionally mottled; aril 1.5–2 mm long, c. 1 mm high, with base 1–1.2 mm long; lobe commonly overhanging base.

Selected specimens of c. 100 examined: **NEW SOUTH WALES**: 1.9 km from lighthouse toward Arakoon, Trial Bay, *J.Armstrong 8*, 25.viii.1972 (NSW); 8 km N of Bowraville, *C.Betteridge*, 28.viii.1971 (NSW); Carlotta Ave, Richmond Park, Gordon, *R.O.Makinson 49*, 8.ix.1985 (NSW); Wentworth Falls, i.1915 (NSW); Mt Solitary, 8 km S of Katoomba, *E.F.Constable s.n.*, 11.xi.1960 (NSW); Dalrymple Nature Reserve, Pymble, *M.J.Taylor 115*, 9.xi.1983 (BRI, MEL676322, NSW); Tarougra Forest Road, 2 km E of Bodalla along Potato Point Road, *E.Mullins 696*, 6.x.1986 (CANB, MEL714731); Duckhole Rd, c. 1.7 km S of its intersection with the final 5 km track to Saltwater Creek Camping Ground, *D.E.Albrecht 781*, 18.ix.1984 (MEL674058); Montreal, Wallaga Lake Rd, corner of track to Camel Rock, *N.Schultz 112*, 3.ix.1994 (MEL2191152, NSW); Track to Mt Imlay, c. 20 km SW of Eden, *R.Coveny 5795 & J.Armstrong*, 15.x.1974 (AD, BRI,

CANB, MEL602810, NSW, PERTH). **VICTORIA**: 5.5 km WNW of Gelliondale PO, 12 km WSW of Yarram PO, *A.C.Beauglehole 62463*, 11.xii.1978 (MEL1S0818S); Chessum Rd, 0.7 km W from junction with Limestone Quarry Rd, Holey Plains State Park, *M.G.Corrick 9986 & B.J.Conn*, 14.x.1986 (CANB, MEL685997, NSW); Cicada Trail, Mueller R., E side, Croajingolong National Park, *A.J.Whalen 669 & D.Mallinson*, 10.x.2002 (CANB, MEL2271193); Princes Hwy, c. 6 km E of Cann R., *T.B.Muir 1934*, 26.xi.1960 (MEL602809); 14 km S of Tarwin Lower on road to Walkerville, West Gippsland, *I.R.Thompson 1161*, 10.x.2009 (AD, BRI, HO, MEL). **TASMANIA**: c. 25 km N of Launceston, *R.Gunn 1016*, 21.x.1842 (NSW); S side of Croppies Point Rd, *A.M.Buchanan 1745*, 24.xi.1983 (HO); SW side of Mt Andrew, *P.Collier 969*, 3.xi.1985 (HO); Road W to Eagle Hawk Tier, NW of Nunamara, *A.V.Ratkowsky*, 16.xi.1991 (HO); N of Priory, *A.M.Buchanan 14916*, 19.xi.1997 (HO).

Flowering period: Flowers spring.

Distribution and habitat: Occurs in far eastern New South Wales S from Urunga in the north-east of the state, in south-eastern Victoria as far west as Walkerville, and in north-eastern Tasmania (Fig. 3). Grows in open forest.

Notes: *Platylobium parviflorum* can generally be identified when sterile by the high length to width ratio and more spreading secondary venation of leaves. Leaves are not cordate at the base, whereas this feature is common in *P. formosum*, *P. reflexum* and *P. montanum* subsp. *montanum*. A typical leaf is shown in figure 1b. The indistinct petiole-petiolule articulation (Fig. 1c) sets it apart from all species except *P. formosum* and *P. triangulare*. The flowers of *P. parviflorum* is of similar size to those of *P. montanum*, but the standard is generally less extensively marked purple-red on its abaxial surface. *Platylobium parviflorum* tends to have a broader pod-wing and a shorter stipe than *P. montanum*.

In the Mt Imlay area in far south-eastern New South Wales (eg. *R.Coveny* 5795, AD, BRI, CANB, MEL, NSW, PERTH; *M.Crisp 4591*, CANB, NSW) leaves are quite narrow and have an unusually high length:width ratio.

The rust fungus *Aecidium* has been noted on pods of this species, eg. *Muir 1934* (MEL). Infection of pods by species of *Aecidium* is also seen in other genera of the Bossiaeeae, including *Bossiaea* and *Goodia*.

5. *Platylobium montanum* I.Thomps., *sp. nov.*

A P. formoso Sm. foliis manifeste unifoliolatis, petiolo longiore plerumque, squamis et bracteis longioribus glabris, calyce breviore, stipite leguminis calyce excedens, ala leguminis angustiore differt.

Type: Victoria. Wabonga Plateau State Park, 10 km south of Whitfield, *A.D.J.Piesse 370*, 1.x.1986; holotype: MEL685291.

Weakly erect, sprawling or prostrate shrubs, to c. 1.5 m high, or to c. 2 m if supported. *Stipules* 3–5 mm long, 1–2.5 mm wide. *Leaves* commonly all opposite, sometimes a proportion alternate; petiole 2–12 mm long; petiole-petiolule articulation distinct; lamina broad-ovate to ovate, to c. 50 mm long, to c. 40 mm wide, with l:w ratio 1–1.8(–2); baso-lateral points not developed; base often cordate to deeply cordate, occasionally truncate or broadly rounded; margin nearly flat to slightly revolute; apex subacute to narrowly acute, with apiculum to c. 2 mm long, often spine-like, not pungent; upper surface commonly moderately tuberculate, secondary veins angled forward at c. 45° at widest part of leaf; lower surface glabrescent; midrib c. 0.5 mm wide. *Inflorescences* 1–4 per axil; scales up to 14, glabrous except for margins; scale-bract cluster 4–10 mm long, occasionally bract and distalmost scale separated by up to 10 mm from cluster; bract 3–6 mm long; pedicel 5–25 mm long; bracteoles inserted 1–7 mm below receptacle, 4–10 mm long, (1.5–)2–4 mm wide (flattened), convex throughout, not reflexing, or occasionally slightly reflexed at the tip, striations obscure or distinct, glabrous or with medial hairs or rarely hairy all over, brown to red-brown. *Calyx* 5–8(–10) mm long, with a scattered or more often dense indumentum of appressed hairs; upper lobes 3–6 mm long, 3–7 mm wide; lower lobes 1–2.5 mm long; standard 10–15 mm long, 12–22 mm wide, with claw 2.5–3.5 mm long; abaxial surface purple-brown throughout or with narrow yellow bands at sides; wings 9–11 mm long, 3–5 mm wide, yellow, sometimes patchily marked red; keel 9–10 mm long, 4–6 mm wide; style 4–5 mm long. *Pods*: stipe (7–)10–15(–20) mm long; body 15–40 mm long, 8–13(–17) mm wide including wing 1–2(–3) mm wide, dark brown or grey-brown, mostly up to 6-seeded; sutures hairy or rarely glabrous; valves with scattered hairs all over, or occasionally with hairs restricted to seed zone or glabrous; funicles c. 1 mm long. *Seeds* 2.5–3.5 mm long, 1.8–2.5 mm wide, mid or dark brown, sometimes speckled; aril 1.5 mm long, c. 1 mm high, with base c. 1.2 mm long; lobe overhanging base.

Key to subspecies of *Platylobium montanum*

1 Plants weakly erect or sprawling, not covering large areas; flowering and fruiting consistently occurring (petiole generally < 1/5 of lamina length; lamina commonly moderately to deeply cordate) ..... **5a.** subsp. ***montanum***

1: Plants prostrate, covering large areas; flowering sporadic and fruit development rare (petiole usually ≥ c. 1/5 of lamina length; lamina rounded to shallowly cordate) ..... **5b.** subsp. ***prostratum***

Etymology: The epithet refers to the occurrence of this species on mountain ranges of the Great Divide of south-eastern Australia (From Latin: *montanus*, of mountains).

Notes: There are two subspecies.

5a. *Platylobium montanum* subsp. *montanum*

Weakly erect or sprawling shrubs, not rooting at nodes, not covering large areas. *Leaves* generally all opposite; petiole mostly 2–5 mm long, occasionally to c. 8 mm long in a small proportion of leaves; base of lamina mostly shallowly to deeply cordate, less often truncate or rounded. *Pedicels* 5–15(–20) mm long; bracteoles inserted 0.5–2 mm below receptacle. *Flowers* usually abundant each season; calyx 5–7 mm long, with upper lobes 3–5 mm wide; lower lobes 1–1.8 mm long. *Pods* usually several to many on a plant. (See species description for information on pods and seeds.)

Selected specimens of c. 160 examined: **NEW SOUTH WALES:** Gulf Stream, Winburndale Nature Reserve, 20 km E of Bathurst, *R.Coveny 9621*, 2.x.1977 (NSW); Rydal, c. 8 km W of Lithgow, *A.Morris*, 14.x.1924 (AD, N5W); Along Junction Pt Rd, 1.9 km N of its junction with the Bigga to Binda Rd, *R.J.Bayer NSW-98054*, 4.x.199B (CANB); Two Sticks Rd near A.C.T. border, *M.Groy 5759*, xi.1965 (CANB, MEL); 6.B km E of Khancoban PO on the Alpine Way to Thredbo, *B.Archer 500*, 23.xii.1996 (CANB, MEL2036310, NSW); Batlow, *J.Boormon*, x.1916 (BRI, N5W); W of and close to Princes Hwy near Narrabarba, *A.Lee*, i.1974 (N5W); Minjary National Park, 3.3 km SSE of Minjary Mountain and c. 9 km NW of Tumut, *I.Crawford 6758*, 9.xi.2001 (CANB, N5W). **AUSTRALIAN CAPITAL TERRITORY:** 12 km W of Condor Creek crossing on Brindabella Rd, *G.Stewart 223 & B.O'Shea*, 1B.x.1984 (CANB); Near Blundells Flat, 3 km S of Mt Coree, *B.J.Lepschi 110*, 26.ii.19B9 (CANB). **VICTORIA:** Lake Mountain, *D.B.Foremon 1042 & R.Filson*, 1S.x.1985 (CANB, MEL1546273, NSW); S river bank at Bundara R. bridge, 31.5 km NW of Omeo on Omeo–Mitta Mitta Rd, *J.H.Ross 3423*, 2B.x.1990 (AD, BRI, CANB, HO, N5W); Road down from Falls Creek, c. 15 km from Omeo Road, *J.D.M.Pearson*, 20.xi.1966 (MEL574935); King Spur Track, c. 3B km N of Dargo, *R.A.Kilgour 196*, 1.ii.19B2 (MEL603359); Intersection of Freestone Ck Rd and Ten Mile Track, 3 km WNW of Moornapa Fire Tower, *R.A.Kilgour 327*, 25.x.1982 (MEL629410); Mt Oberon car park, Wilsons Promontory, *M.G.Corrick 7090*, 7.xi.19B0 (MEL576034); 0.7 km S of Kinglake, *H.I.Aston 347*, 2B.ix.1959 (MEL602838); c. 11 km N of Mt Victory Rd, Mt Difficult Range, Grampians National Park, *A.C.Beauglehole 30923*, B.ix.1969 (MEL602B22, NSW); Dearden Track, 5W of Taradale, *I.R.Thompson 1165*, 13.x.2009 (CANB, MEL, N5W); Melba Hwy, Ronans Well, between Dom Dom picnic ground and Black Spur, *I.R.Thompson 1216*, 4.i.2010 (MEL).

Flowering period: Flowers spring.

Distribution and habitat: Occurs along the Great Divide in south-eastern New South Wales, south from Orange, the Australian Capital Territory and Victoria. In Victoria it extends as far west as Taradale in south-central Victoria with somewhat disjunct occurrences further west in the Grampians Ranges and further south in Wilsons Promontory (Fig. 3).

Notes: *Platylobium montanum* subsp. *montanum* commonly has leaflet-laminas with a pronounced cordate base and short petioles, which has the effect of making the leaves appear more or less sessile (Fig. 4a). Bracteoles of *P. montanum* are convex and typically quite long relative to the length of the somewhat silky calyx (Fig. 4b). At locations between Castlemaine and Malmsbury in south-central Victoria (eg. *I.R.Thompson 1165* MEL, *Mueller* MEL), bracteoles are shorter than usual and also unusually are hairy all over.

Pods are commonly covered with hairs, and the hair density is relatively high, such that early in development the surface is completely obscured by white appressed hairs. However, in the Southern Tablelands of New South Wales, eg. around Tumut (eg. *Crawford 6758* CANB, NSW), pod valves are sometimes hairless. Also in some of these populations the pods and pod-wings are unusually broad.

Platylobium parviflorum is perhaps closest to *P. montanum* subsp. *montanum* in bract, bracteole and floral morphology. Apart from the difference in the structure of the petiole-petiolule articulation, *P. montanum* subsp. *montanum* differs from *P. parviflorum* in having leaflets with a lower length:width ratio and

a cordate base, scales, bracts and bracteoles that are typically longer and less distinctly striate, calyces with a denser indumentum, and the abaxial surface of the standard more extensively marked with red.

Platylobium montanum subsp. *montanum* is distinguishable from subsp. *prostratum* by its more erect habit. The two subspecies have been seen growing together near Taradale in south-central Victoria and were readily distinguished by both habit and leaf morphology at that site. Some specimens collected from where the two subspecies overlap in distribution are difficult to place to subspecies level, which raises the possibility that these specimens are hybrids. Leaf morphology of the two subspecies is shown in Figure 4.

5b. *Platylobium montanum* subsp. *prostratum* I.Thomps., *subsp. nov.*

A subspecie typica plantis prostratis raro fertilis, petiolo longiore, foliis minus valde cordatis differt.

Type: Victoria. Mt Slide Rd between Yarra Glen and Kinglake, north of Greenwood Lane, *M.G.Corrick 10212*, 4.x.1986; holotype: MEL; isotype: CANB.

Prostrate shrubs, rooting at nodes, covering large areas. *Leaves* all opposite or with a proportion of leaves alternate; petiole 3–15 mm long; base of lamina shallowly cordate, truncate or rounded. *Pedicels* 15–25 mm long; bracteoles inserted 1–7 mm below receptacle. *Flowering* apparently unreliable and plants generally not very floriferous; calyx 6–10 mm long, with upper lobes 4–7 mm wide; lower lobes 1.5–2.5 mm long. *Pods* rarely developed; stipe 8–10 mm long; body 20–25 mm long, 12–14 mm wide, including wing c. 1 mm wide, grey-brown, up to 3-seeded; sutures hairy, valves with scattered hairs. *Seeds* 3.2 mm long, 2.2 mm wide, dark brown; aril 1.5 mm long, c. 1 mm high, with base c. 1.2 mm long; lobe not overhanging base. (Pod and seed data based on *Thompson 1384* MEL.)

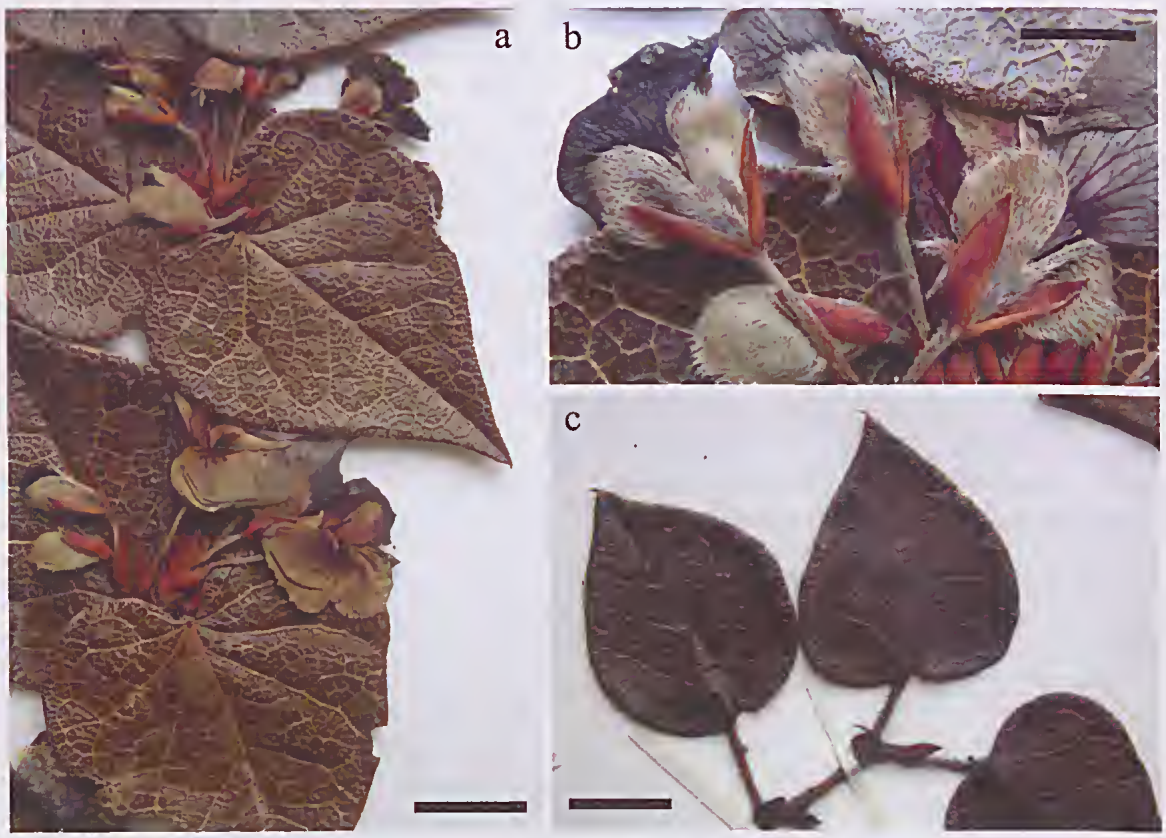

Figure 4. *Platylobium montanum* subsp. *montanum*. a. Leaves and inflorescences; b. flowers and bracteoles (a & b *A.D.J.Piesse 370* MEL); c. *P. montanum* subsp. *prostratum*, leaves (*H.B.Williamson*, 1915 MEL). Scale bars: a & c = 10 mm, b = 5 mm.

***Selected specimens of c. 20 examined*: VICTORIA:** Mt Cole, *H.B.Williomson*, xi.1915 (MEL, NSW); Cypress Drive, c. 1.5 km NW of Taradale, *I.R.Thompson 1384*, 21.xii.2010 (CAN8, MEL); Antonios Track, 4 km WSW of Taradale, *E.E.Perkins s.n.*, 30.xi.2008 (MEL); 4 km S of Gisborne beside Hobbs Rd, *T.B.Muir 4989*, 6.x.1971 (MEL); Near Kilmore water supply dam, Mt Disappointment, *M.G.Corrick 5680*, x.1976 (MEL547668); Kilmore, *J.W.Dwyer*, x.1918 (NSW); Nicholson-Mt Alfred State Forest, *A.C.Beauglehole 77285*, 23.ix.1984 (MEL671303); Avon-Mt Hedrick natural feature, scenic reserve, *A.C.Beouglehole 77885*, 5.x.1984 (MEL671304); 14.2 km NE of Moe, on road to Erica, *D.E.Albrecht 1874*, 25.ix.1985 (MEL); Ben Cruachan natural feature, scenic reserve, *A.C.Beauglehole 78013*, 6.x.1984 (MEL671301); 4.5 km along Collins Rd off Bruthen–Omeo Rd, road to summit of Mt Elizabeth, Mt Elizabeth no. 2 State Forest, *J.H.Ross 3202*, 14.x.1986 (AD, 8RI, CANB, HO, MEL113635, NSW).

***Flowering period*:** Flowers spring.

***Distribution and habitat*:** Occurs on the southern side of the Great Divide in southern Victoria from Mt Cole east to Buchan (Fig. 3).

***Etymology*:** The subspecific epithet refers to the habit of the plants (From Latin: *prostratus*, prostrate).

***Notes*:** *Platylobium montanum* subsp. *prostratum* resembles *P. infecundum* and *P. rotundum* in habit and leaf morphology, and in having very low fertility. Compared to *P. infecundum*, it differs in having shorter petioles, less discolorous leaves, a denser and more appressed calyx indumentum, and much broader, more convex and non-recurving bracteoles that are red-brown rather than orange-brown.

Unlike in *P. rotundum*, at least some leaves on a plant of *P. montanum* subsp. *prostratum* are opposite. Also, in the latter the leaflet apex is generally more acute, the petiole is shorter, and bracteoles are larger and mostly inserted closer to the receptacle. *Platylobium montanum* subsp. *prostratum* is in several respects intermediate in nature between *P. montanum* subsp. *montanum* and *P. rotundum*, which hints at a hybrid origin for the subspecies.

A few specimens from eastern Victoria have been identified as subsp. *prostratum*; however, field examination is desirable to confirm that they have a similar habit to the several populations seen in south-central Victoria and whether they are similarly reluctant to flower or produce fruit. Specimens from Mt Elizabeth No. 2 north of Bairnsdale have leaves with a relatively long lamina and so the ratio of lamina length to petiole length is higher than is typical for subsp. *prostratum*.

6. *Platylobium reflexum* I.Thomps., *sp. nov.*

A P. formoso *Sm. foliis manifeste unifoliolatis, squamis glabris, bracteolis lanceolatis, calyce breviore, ala leguminis angustiore, seminibus minoribus differt; a* P. montano *I.Thomps. petiolo breviore, bracteolis reflexis aurantico-brunneis, stipite leguminis breviore differt.*

***Type*:** Victoria. Gembrook–Launching Place Rd, opposite Swallowfield Rd, c. 5 km NNE of Gembrook, *I.R.Thompson 1108*, 6.xi.2008; holotype: MEL; isotype: CANB.

P. formosum var. *cordifolium* Wawra, *Itinera Principum S. Coburgi* 1: 11 (1883). ***Type*:** Victoria. Dandenong, *Wawra coll. 1 587*, date unknown; holo: W, image seen MEL.

Weakly erect shrubs, to c. 1 m high, or to c. 2 m high when supported. *Stipules* 3–6 mm long, 1.5–2.5 mm wide. *Leaves* predominantly opposite, occasionally a proportion alternate; petiole mostly 1–3 mm long, occasionally proximal leaves with petiole up to c. 8 mm long; petiole-petiolule articulation mostly distinct; lamina ovate, to c. 60 mm long, to c. 40 mm wide, with l:w ratio mostly 1.2–1.8; baso-lateral points not developed; base cordate to truncate; margin recurved; apex acute, with apiculum to c. 1 mm long, spine-like but not pungent; upper surface smooth or minutely tuberculate; secondary veins angled forwards at 30–45° at widest part of leaf; lower surface glabrescent; midrib 0.5–0.7 mm wide. *Inflorescences* 1–4 per axil; scales 6–10, glabrous, scale-bract cluster 8–10 mm long, or occasionally distal-most scale separated by up to c. 5 mm from cluster; bract 4–5 mm long; pedicel 10–35 mm long, with spreading or appressed hairs 0.5–1 mm long; bracteoles inserted c. 1 mm below receptacle, 3–7 mm long, (1–)1.5–2.5 mm wide, ±flat in distal half, commonly becoming reflexed at or after flowering, distinctly striate, glabrous, or uncommonly with medial hairs, orange-brown. *Calyx* (5–)6–8 mm long, with a sparse to scattered indumentum of appressed to spreading hairs, occasionally glabrescent; upper lobes 3.5–6 mm long, 3.5–5 mm wide; lower lobes 1.5–2 mm long; standard 10–15 mm long, 15–25 mm wide, with claw 2.5–3 mm long; abaxial surface purple-brown throughout or yellow at sides; wings 10–12 mm long, 4–5 mm wide, entirely yellow; keel 9–11 mm long, 4–5 mm wide; style 4–6 mm long. *Pods*: stipe 5–11 mm long;

body 20–40 mm long, 8–12 mm wide, including wing 0.6–2 mm wide, dark grey, mostly 3–8-seeded; sutures hairy, valves with sparse to scattered long spreading hairs concentrated medially; funicles c. 1 mm long. *Seeds* 2.5–3 mm long, 1.5–1.8 mm wide, mid to dark brown or blackish, sometimes speckled; aril 1.5 mm long, c. 1 mm high, with base 1.2 mm long; lobe not or slightly overhanging base.

***Selected specimens of c. 50 examined*: VICTORIA**: Tarago Rd, 5.3 km W of Tarago River Crossing, 7 km WNW of Neerim, *N.G.Walsh s.n.*, 3.ix.1983 (MEL644429); c. 16 km from Noojee toward Powelltown, *E.J.Carroll*, 20.xii.1965 (CANB); Dandenong, *C.Walter*, no date (NSW); Launching Place, *K.Cowle*, no date (MEL); SW of Powelltown on Torbert Rd, just W of its junction with Gilderoy Rd, *M.G.Corrick 8633*, 22.ix.1983 (MEL644969); Intersection of Gembrook Rd and Mt Eirene Rd, c. 3 km S of Gembrook, *I.R.Thompson 1132*, 20.xii.2008 (CANB, MEL); Chapple Vale–Lavers Hill Rd c. 4.5 km SE of turnoff from Chapple Vale–Kennedys Creek Rd, *I.C.Clarke 2157*, 1.xii.1992 (BRI, CANB, MEL2017973); c. 6 km S of Lavers Hill on road to Glen Aire, *B.G.Briggs 2965*, 23.x.1969 (NSW); Between Lavers Hill and Apollo Bay, *D.J.E.Whibley 84*, 22.x.1957 (AD).

***Flowering period*:** Flowers spring.

***Distribution and habitat*:** Occurs in the Otway Ranges in south-western Victoria and between the Dandenong Ranges and Fumina in south-central Victoria where locally very common (Fig. 6). A specimen at AD (*E.Ashby*, xi.1937) with a few flowers and a single pod is labelled as occurring in the Grampians. Although this locality is feasible, the labelling is considered to be in error unless evidence of the existence of the species in the Grampians is confirmed. The appressed indumentum of pedicels and calyx of this specimen is suggestive of the Otway Ranges form of *P. reflexum*. Grows in tall open forest.

***Etymology*:** The epithet refers to the bracteoles which are commonly conspicuously reflexed (From Latin: *reflexus*, reflexed).

***Notes*:** The shape of the leaflet-lamina of *P. reflexum* is similar to that of *P. formosum* but its leaves can be distinguished from the latter by the presence of a distinct ridge at the petiole-petiolule articulation (Fig. 1b). *Platylobium montanum* subsp. *montanum* has similar leaf morphology and the two species can be difficult to distinguish in the absence of reproductive structures. In *P. montanum* subsp. *montanum* the petiole is generally slightly longer and the leaf-base is more deeply cordate but these features will not consistently distinguish the two taxa. Bracteoles of *P. reflexum* have a distinct herbaceous patch at the base and this is another way in which this species differs from *P. montanum*. A typical example of the reflexed bracteoles of *P. reflexum* is shown in figure 2a. *Platylobium infecundum* q.v. has similarly shaped and reflexed bracteoles except that they are generally significantly smaller. Reflexed bracteoles also occur variably in *P. formosum* and *P. triangulare*; however, because of their smaller size and lower length:width ratio, the feature is less conspicuous.

Plants in the Otway Ranges in south-western Victoria have an indumentum of short appressed hairs on the pedicels and calyces, whereas in south-central Victoria hairs on these structures are almost always long and spreading.

7. *Platylobium infecundum* I.Thomps., *sp. nov.*

A P. reflexo *I.Thomps. foliis saepe alternis, petiolo longiore, bracteolis minoribus differt; a* P. montano *I.Thomps. petiolo longiore plerumque, pilis longioribus, pedicellis longioribus, bracteolis minoribus recurvatis differt.*

***Type*:** Victoria. H.E. Parker Reserve, Heathmont, *I.R.Thompson 1104*, 4.x.2008; holotype: MEL.

Prostrate shrubs, rooting at nodes. *Stipules* 3–6 mm long, 1.5–2.5 mm wide. *Leaves* alternate and opposite in various proportions; petiole (2–)5–25 mm long; petiole-petiolule articulation distinct; lamina broad-ovate, triangular-ovate or rotund, mostly to c. 40 mm long, to c. 40 mm wide, with l:w ratio 0.9–1.6; baso-lateral points not developed; base mostly slightly cordate to truncate; margin mostly flat to slightly recurved, sometimes revolute; apex rounded to subacute or occasionally acute, with apiculum to c. 1 mm long, not pungent, mostly brittle; upper surface mildly tuberculate; secondary veins angled forward at 30–45° at widest part of leaf; lower surface glabrescent; midrib c. 0.4 mm wide. *Inflorescences* 1–3 per axil; scales 6–10, glabrous; scale-bract cluster 5–6 mm long, or occasionally with distalmost scale inserted several mm from cluster; bract 3–5 mm long; pedicels mostly 15–40 mm long; bracteoles inserted 0.5–5 mm below receptacle, 2–5 mm long, 0.8–1.5 mm wide, ±flat, mostly

becoming reflexed, striate, glabrous or with a few midline hairs, orange-brown. *Calyx* 5.5–9 mm long, with a sparse to scattered indumentum of long, spreading or occasionally appressed hairs; upper lobes 4–6 mm long, 3–4.5 mm wide; lower lobes 0.8–1.5 mm long; standard 10–13 mm long, 15–20 mm wide, with claw 2.5–3 mm long; abaxial surface purple-brown throughout; wings 10–12 mm long, 3–4 mm wide, sometimes marked red; keel 9 mm long, 5 mm wide; style 4–5 mm long. *Pods* (a single immature pod recorded for the species): stipe 7 mm long; body 20 mm long, 12 mm wide, including wing 1.2 mm wide; sutures hairy, valves very sparsely hairy with long spreading hairs. *Mature seeds* not seen.

Selected specimens of c. 25 examined: **VICTORIA:** Courtney's Road, Belgrave South, *I.R.Thompson 1362*, 4.xii.2010 (MEL); Boronia, near railway line, NW of town, *T.B.Muir 478*, 28.ix.1958 (MEL602815); Sassafras, *P.R.H.St. John*, 6.x.1900 (MEL559320); Former Lilydale-Warburton Railway line 20 m E of intersection with York Road,.*D.J. van Bockel 49*, 12.x.1987 (MEL1588804); Ringwood, *A.Morrison*, 24.ix.1895 (CANB); Ferntree Gully, *C.Davis*, 8.xi.1942 (NSW); Maroondah Hwy, c. 5 km NE of Healesville, *I.R.Thompson 1366*, 11.xii.2010 (MEL); Healesville to Black Spur, *A.Meebold 2015*, xii.1928 (AD); Lysterfield, *A.Morris*, 3.x.1925 (AD).

Flowering period: Flowers spring to mid-summer.

Distribution and habitat: Occurs in the outer eastern suburbs of Melbourne, and near Healesville in south-central Victoria (Fig. 6). Currently known from four localities. Grows in open forest.

Etymology: The epithet refers to the paucity of fruit and seed development in this species (From Latin: *in-*, not and *fecundus*, fertile).

Notes: There had been no records of pod development in this species until recently when a single plant bearing a semi-mature pod was discovered in South Belgrave (*Thompson 1394* MEL). *Platylobium infecundum* is perhaps most closely related to *P. reflexum* based on similarities in indumentum and bracteole morphology. The hairs on pedicels and calyces are commonly relatively sparse but long and spreading. Bracteoles, although markedly smaller, are a similar shape and colour to those of *P. reflexum* and they become reflexed similarly. In terms of habit and petiole length, *P. infecundum* is more similar to *P. montanum* subsp. *prostratum* and *P. rotundum*. Although *P. reflexum* occurs in areas close to *P. infecundum*, the two species have not been recorded growing together. *Platylobium reflexum* grows in taller forests and at slightly higher altitudes than *P. infecundum*.

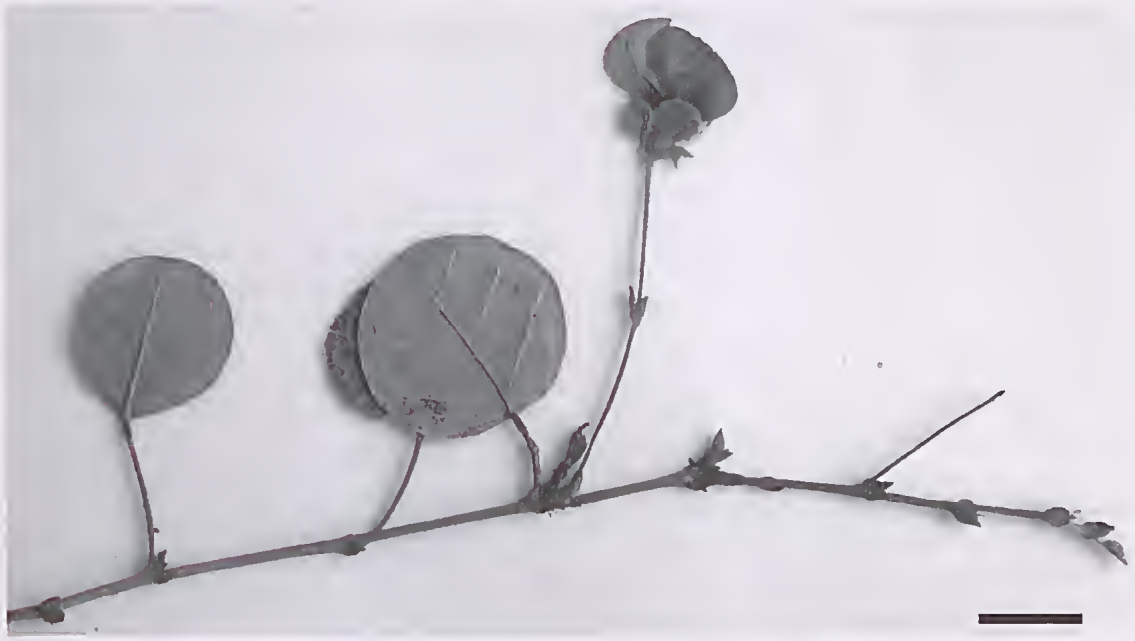

Figure 5. *Plotylobium rotundum* (*I.R.Thompson 1164* HO).

8. *Platylobium rotundum* I.Thomps., *sp. nov.*

A P. formoso *Sm. plantis prostratis, foliis alternis, pedicellis longioribus, bracteolis insertis plus proximalis differt; a P. alternifolio F.Muell. petiolo longiore, squamis fasciculatis, calyce hirsuto, pedicello longiore differt.*

Type: Victoria. Swankey Gully Track, 3.7 km W of Malmsbury, *I.R.Thompson 1164*, 13.x.2009; holotype: MEL; isotype: CANB, HO.

Prostrate shrubs, rooting at nodes, sometimes forming extensive mats. *Stipules* 2–3 mm long, 1–1.5 mm wide. *Leaves* alternate; petiole 8–25 mm long; petiole-petiolule articulation distinct; lamina broad-ovate, broad-elliptic or c. circular, 10–40 mm long, 8–35 mm wide, with l:w ratio mostly 1–1.3; baso-lateral points absent; base broadly rounded or truncate, less often slightly cordate; margin ±flat; apex subacute or more often obtuse to rounded, with apiculum to c. 1 mm long, generally brittle; upper surface variably tuberculate, secondary veins angled forwards at 30–45° at widest part of leaf; lower surface glabrescent; midrib c. 0.4 mm wide. *Inflorescences* 1 or 2 per axil; scales 8–14, glabrous; scale-bract cluster 3–6 mm long, sometimes distalmost scale inserted several mm distal to cluster; bract 2–6 mm long; pedicel (10–)20–50 mm long; bracteoles inserted c. in middle third of pedicel, 5–30 mm below receptacle,

Figure 6. Distributions of a. *Platylobium reflexum*, b. *P. infecundum*, c. *P. rotundum*, and d. *P. alternifolium*.

2–6 mm long, 1–2 mm wide, flat or convex, sometimes reflexing, striate, glabrous or patchily hairy, brown or orange-brown. *Calyx* 5–6 mm long, with a fairly sparsely indumentum of appressed hairs; upper lobes 3.5–5 mm long, 3–4 mm wide; lower lobes 1.5–2.5 mm long; standard 12 mm long, 18 mm wide, with claw c. 3 mm long; abaxial surface purple-brown throughout; wings 8–12 mm long, 4–5(–6) mm wide, yellow, commonly with red markings; keel 7–10 mm long, 5–6 mm wide; style 4–5 mm long. *Pods*: stipe 7–12 mm long; body 10–16 mm long, 8–10 mm wide including wing 0.8–1 mm wide, purplish-brown, 1-seeded (very few seen); sutures hairy, valves glabrous or with scattered long hairs in zone overlying seeds; funicles 1.5 mm long. *Seeds* 3 mm long, 2 mm wide, dark brown; aril 1.2 mm long, 0.8 mm high, with base 1.2 mm long; lobe not overhanging.

***Selected specimens of c. 12 examined*: VICTORIA:** Mt Buangor, c. 27 km E of Ararat PO, *A.C.Beauglehole 61357*, 5.xi.1978 (MEL649738); Humboldt [track] off Swankey Gulley Track, 3.7 km W of Malmsbury, *E.Perkins*, 30.xi.2008; 1.4 km E of Malmsbury Railway Station, *E.E.Perkins*, 10.x.1991 (MEL); Hepburn Golf Links, *F.Robbins*, xi.1945 (MEL2093292); Ben Nevis, *C.Green* (MEL569727); Walking track, near Cave Hill, Mt Buangor State Forest, *I.R.Thompson 1169*, 2.xi.2009 (AD, BRI, HO, CANB, MEL); Newbury, *H.B.Williamson*, xi.1915 (NSW).

***Flowering period*:** Flowers spring.

***Distribution and habitat*:** Occurs in central and central-west Victoria from Mt Buangor east to Blackwood (Fig. 6). Grows in open forest.

***Etymology*:** The epithet refers to the shape of the leaflet-lamina (From Latin: *rotundus*, nearly circular).

***Notes*:** *Platylobium rotundum* is a distinctive species recognisable by its prostrate habit, entirely alternate, long-petiolate leaves, very long pedicels and the bracteoles inserted remotely from the calyx. The often almost circular lamina of the leaflet is also reasonably distinctive. *Platylobium alternifolium* is the only other species to have entirely alternate leaves. *Platylobium rotundum* rarely produces fruit, and the descriptions of pods and seeds are based on two separate collections from near Malmsbury, in south-central Victoria, the only locality where these have been collected.

Examination of fresh material has shown that stamen-filaments of *P. rotundum* are purple, unlike the white filaments seen in other species. An image of a pressed specimen of *P. rotundum* is presented in figure 5.

9. *Platylobium alternifolium* F.Muell., *S. Sci. Rec.* 3: 99 (1883)

***Type*:** Victoria. Mt William, *D.Sullivan*, 1883; lectotype: MEL569729, *fide* J.H.Ross, *Muelleria* 5(2): 129 (1983).

[Residual syntypes: Mt William, *D.Sullivan*, 1882 (MEL569728) = *P. alternifolium*; Mt Disappointment, *F.Mueller*, 1852 (MEL) = *P. montanum* subsp. *prostratum*; Mt Ben Nevis, *C.Green*, date unknown (MEL) = *P. rotundum*]

Prostrate shrubs, rooting at nodes, often forming extensive mats. *Stipules* 2–3 mm long, 1–2 mm wide. *Leaves* alternate; petiole 5–15 mm long; petiole-petiolule articulation distinct; lamina ovate or triangular-ovate, 10–30 mm long, 10–25 mm wide, with l:w ratio mostly 1–1.5; baso-lateral points absent; base mostly cordate to deeply cordate, occasionally c. truncate; margin flat to slightly recurved; apex obtuse to acute, with apiculum to c. 0.5 mm long, not pungent; upper surface smooth or tuberculate, secondary veins angled forwards at 15–30° at widest part of leaf; lower surface glabrescent; midrib c. 0.4 mm wide. *Inflorescences* mostly 1 per axil; scales 6–10, glabrous, inserted at intervals along axis, rather than forming a cluster; bract 4–5 mm long, inserted up to c. 1 mm from base of pedicel; pedicel 4–8 mm long, glabrous; bracteoles inserted 2–5 mm below receptacle, 5–7 mm long, 2–3 mm wide, strongly convex, not reflexing, usually striate, glabrous, sometimes pale or pinkish. *Calyx* 7–8 mm long, glabrous except for marginal cilia; upper lobes 4.5–6 mm long, 3–4 mm wide; lower lobes 0.8–1.5 mm long; standard 12–14 mm long, 14–18 mm wide, with claw c. 3 mm long; abaxial surface purple-brown throughout or nearly so; wings 9–11 mm long, c. 3 mm wide, sometimes marked red; keel 9–10 mm long, 4–5 mm wide; style 4–5 mm long. *Pods*: stipe 2–3 mm long; body 15–20 mm long, 10 mm wide, including wing 1–1.5 mm wide, dark brown or grey-brown, up to 6-seeded; sutures hairy, valves glabrous; funicles c. 1 mm long. *Seeds* (few seen) 3 mm long, 2 mm wide, pale or dark brown; aril c. 1 mm long, c. 1 mm high, with base c. 1 mm long; lobe not overhanging base.

***Selected specimens of c. 15 examined*: VICTORIA:** c. 4 km S along Mt Difficult Rd from junction with East Wartook Track, *J.V.Yugovic 241*, 31.x.1985 (MEL680261); Mt Difficult Range [East], *A.C.Beauglehole 30754*, 2.vi.1979 (MEL99431); c. 0.8 km down road from

lookout over Treefern Gorge, NW of summit of Mt William, *A.C.Beauglehole 30405A*, 31.i.1969 (MEL99436); Bolangum Ranges, *J.W.Audax*, xi.1920 (MEL); Mt Difficult Rd, Grampians, *M.E.Phillips s.n.*, 12.x.1966 (CANB).

Flowering period: Flowers spring.

Distribution and habitat: Occurs in the Grampians Ranges and nearby Bolangum Ranges (a very old record) in south-western Victoria (Fig. 6). Grows in dry sclerophyll forest.

Notes: *Platylobium alternifolium* is a distinctive species with entirely alternate leaves, a glabrous calyx, and bud scales relatively widely spaced along an elongate axis. *Platylobium alternifolium* appears to be variable from season to season in the amount of fruit and seed development. The reticulate leaf-venation is sometimes impressed, at least in dried specimens, and this appearance has not been seen in other species. *Platylobium montanum* subsp. *prostratum* is close to *P. alternifolium* in terms of habit, leaf morphology, and bract and bracteole morphology.

Names of uncertain application (See Ross 1983 for details)

Platylobium gracile **Dum.-Cours.**, *Le Botaniste Cultivateur* 2nd edn, 7: 314 (1814).

Platylobium rotundifolium **Colla**, *Hortus Ripulensis* 1: 110 (1824).

Although *Platylobium rotundum* often has circular leaves, collections of *P. rotundifolium* are not likely to have been made from where *P. rotundum* is known to occur in central Victoria.

Excluded names

Platylobium lanceolatum **Andrews**, *Bot. Repos.* 3: t. 205 (1802).

This is *Bossiaea heterophylla* Vent.

Platylobium microphyllum **Sims**, in Curtis, *Bot. Mag.* 22: t. 863 (1805).

This is *Bossiaea microphyllum* (Sims) Sm.

Platylobium obcordatum **Vent.**, *Jardin de la Malmaison* 1: subt. 31 (1803).

This is *Bossiaea obcordata* (Vent.) Druce.

Platylobium ovatum **Andrews**, *Bot. Repos.* 4: t. 266 (1802).

This is *Bossiaea heterophylla* Vent.

Platylobium reticulatum **Sieb. ex Spreng.**, *Syst. Veg.* edn 16, 3: 231 (1826).

This is *Mirbelia platylobioides* (DC.) Joy Thomps.

Platylobium spinosum **Turcz.**, *Bull. Soc. Naturalistes Moscou.* 26: 284 (1853).

This is *Bossiaea spinosa* (Turcz.) Domin

Acknowledgments

I am grateful to the Royal Botanic Gardens, Melbourne, particularly Alison Vaughan and the collections staff for their assistance with mapping and loan processing, and to the directors of AD, BRI, CANB, HO, MEL, and NSW for making their collections available for study. This study was funded by a grant from the Australian Biological Resources Study (ABRS Grant no. 207-01), which is a program within the Department of Sustainability, Environment, Water, Population and Communities.

References

James, T.A. (2002). '*Platylobium*'. In G.J.Harden (ed.), *Flora of New South Wales, revised edn*, **Vol. 2**, p. 516. UNSW Press Ltd: Sydney.

Ross, J.H. (1983). A revision of the genus *Plotylobium* Sm. (Papilionaceae). *Muelleria* **5**, 127–141.

Thompson, I.R. (2011). A revision of *Muelleranthus*, *Ptychosema* and *Aenictophyton* (Fabaceae: Bossiaeeae). *Muelleria* **29**, 173–189.

Willis, J.H. (1967). Systematic notes on the indigenous Australian flora. *Muellerio* **1**, 127.

A revision of *Muelleranthus*, *Ptychosema* and *Aenictophyton* (Fabaceae: Bossiaeeae)

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Introduction

Tribe Bossiaeeae is a small tribe in family Fabaceae of herbaceous perennials, subshrubs and shrubs. The tribe is endemic to Australia and, as this study commenced comprised six genera and 72 species, 86% of these in *Bossiaea* Vent. The tribe has a widespread distribution in Australia, with the highest species richness in temperate and subtropical latitudes. Members of the Bossiaeeae can be recognised by the combination of their petals which are yellow or orange with red or purple-brown markings, their adaxially open staminal sheath, their uniform and dorsifixed anthers, and the distinctively lobed aril of their seeds. The current membership of the tribe was established in 1987 based on morphology (Crisp & Weston 1987) and a recent phylogenetic study by Crisp and Cook (2003) using molecular data supported this classification. Crisp and Cook's analyses also suggested that the Bossiaeeae is either sister to or nested within tribe Mirbelieae.

The subjects of this paper, the genera *Muelleranthus* Hutch., *Ptychosema* Benth., and *Aenictophyton* A.T.Lee., occur predominantly in arid or semi-arid regions. They are absent from Victoria and Tasmania. Both morphological and molecular analyses (Crisp & Weston 1987; Crisp & Cook 2003), suggest that they form a monophyletic group within the Bossiaeeae, with *Muelleranthus* sister to the other two. However, these molecular analyses only included a total of three species from the three genera.

Taxonomic history: *Ptychosema* and *P. pusillum* Benth. were described in 1839 (Bentham 1839). Subsequently *P. anomalum* F.Muell., *P. trifoliolatum* F.Muell. and *P. stipulare* J.M.Black were included in the same genus. The latter two species, which were distinct from *P. pusillum* in having trifoliolate rather than imparipinnate leaves, were transferred in 1973 to a new genus *Muelleranthus* (Hutchinson 1964). However, it was Lee (1973) who was the first to validly make combinations in this new genus. In the same article, Lee described *Muelleranthus crenulatus* A.T.Lee and erected a new monotypic genus *Aenictophyton* A.T.Lee to accommodate *A. reconditum* A.T.Lee.

Abstract

A taxonomic revision of *Muelleronthus* Hutch., *Ptychosemo* Benth. and *Aenictophyton* A.T.Lee (Fabaceae: Bossiaeeae) is presented. All are Australian-endemic and species are found predominantly in arid or semi-arid regions. A new genus, *Parogoodio* I.Thomps., is erected to accommodate *Paragoodia crenulato* (A.T.Lee) I.Thomps., which is transferred from *Muelleranthus*. *Ptychosemo onomalum* F.Muell. is transferred to *Aenictophyton* and recombined as *Aenictophyton anomolum* (F.Muell.) I.Thomps. Two new species, *Muelleranthus porvolotus* I.Thomps. and *M. obovotus* I.Thomps, and one new subspecies, *Aenictophyton reconditum* subsp. *macrophyllum* I.Thomps., are described. Distribution maps and keys to species are presented. A revised key to genera in tribe Bossiaeeae is also presented.

Keywords: morphology, taxonomy, biodiversity, flowering plants, peas, legumes.

Muellerio 29(2): 173-189 (2011)

Methods

This morphological study utilised herbarium material which was examined with the aid of a dissecting microscope. Pressed flowers were reconstituted using hot soapy water to facilitate examination. Specimens from AD, BRI, CANB, MEL, NSW and PERTH were examined. All images presented were taken by the author using a Canon PowerShot A2000 IS digital camera.

Results

The results of this morphological study are presented in the taxonomic section below. In summary, the pattern of morphological variation identified calls for the placement of *Muelleranthus crenulatus* in a new genus, the transfer of *Ptychosema anomalum* to *Aenictophyton*, and the recognition of two new species of *Muelleranthus* and one new subspecies of *Aenictophyton*.

Taxonomically useful characters identified for the four genera of the study group include: presence and density of indumentum and orientation of hairs; dimensions, shape and texture of stipules; number, length, shape and venation of leaflets; length and robustness of pedicels; number of flowers per raceme; dimensions of bracts, bracteoles and flower parts; the size and presence of a hypanthium; coloration of the petals; stipe length of pods; size, pigmentation, and suture morphology of pods; number of seeds per pod; and aril morphology.

This research forms part of a larger study encompassing all genera in tribe Bossiaeeae. Revisions of *Goodia* Salisb. and *Platylobium* Sm. have been published elsewhere in this volume of *Muelleria* (Thompson 2011a, 2011b).

Taxonomy

Tribe Bossiaeeae

Herbaceous perennials, subshrubs or shrubs to c. 4 m high, sometimes rhizomatous; branches terete or variously compressed. *Stipules* herbaceous or scarious, erect or variously recurved, caducous or persistent, fused to form a scale* at leafless nodes. *Leaves* alternate or opposite, imparipinnate, digitately or pinnately trifoliolate, or unifoliolate; sometimes plants leafless. *Inflorescences* terminal or pseudoaxillary, comprising few or many-flowered racemes, or flowers solitary; sometimes on very short branches bearing 2 to several bud scales; flowers pedicellate; bract and pair of bracteoles persistent or not. *Flowers* with hypanthium or not; calyx tubular, with upper lobes ±free or fused; petals clawed; standard and wing petals yellow or orange, mostly with red or purple-brown markings; wings generally narrower than the keel; keel angular or rounded apically, greenish or maroon; stamens generally all fused to form an adaxially open sheath; anthers all dorsifixed and of similar size; with connective mostly conspicuous. *Pods* short- to long-stipitate, moderately to strongly compressed, with a short beak, with upper suture sometimes ridged or winged; valves often becoming revolute post-dehiscence. *Seeds* generally plump, ellipsoid; aril with an arching vertical lobe.

*Scales which replace leaves in leafless species and bud scales are both formed by the fusion of a pair of stipules. Such scales occur in *Bossiaea* and *Platylobium* only.

1. *Paragoodia* I.Thomps., *gen. nov.*

A Goodia *Salisb. plantis prostratis herbaceis, foliolis crenulatis, bracteis et bracteolis persistentibus, racemis paucifloribus, leguminibus hirsutis differt; a* Muellerantho *Hutch. foliis pinnatim trifoliolatis, foliolis crenulatis, floribus sine hypanthio, leguminibus latioribus hirsutis, arillo majore differt.*

Type: *P. crenulata* (A.T.Lee) I.Thomps.

Prostrate herbaceous perennials, with a vertical rootstock (unknown whether this arises from a horizontal rhizome), sparsely pubescent; stems to 20 cm long, to c. 1 mm in diameter. *Stipules* lanceolate, thin, green at first. *Leaves* pinnately 3-foliolate, or digitately 3-foliolate in smaller leaves; petiole slender, not herbaceous, longer than the leaflets; leaflets with margin crenulate distally; upper surface gland-dotted; lower surface with secondary veins raised. *Inflorescences* terminal or pseudoaxillary (leaf-opposed), determinate, 1–3-flowered; bract and bracteoles persistent; bracteoles inserted distally on pedicel. *Flower-buds* with apex pointed; hypanthium not developed; calyx not striped; calyx-lobes much longer than tube, with apices filiform; upper lobes fused for most of length; lower lobes narrow-triangular, all of similar length or medial lobe slightly longer; petals with markings not of stripes; standard slightly longer than wings; wings c.

equal to keel; keel-apex c. rounded, red-brown; anther connective moderately broad; ovary 4-ovulate; stigma small. *Pods* with stipe shorter than calyx; body c. oblong, subtruncate basally, hairy, without markings. *Seeds*: aril well-developed, with lobe strongly curved.

Notes: The crenulate leaves and the relatively long, narrow calyx-lobes of the single species in *Paragoodia* are not seen in *Goodia*, *Muelleranthus*, *Aenictophyton* or *Ptychosema*; however, these features are seen in a few species of *Bossiaea* from Western Australia. *Paragoodia* resembles *Goodia* in having pinnately trifoliolate leaves, no hypanthium, and a similar pod shape and aril size. Also, the petal colour pattern is very similar to that of an undescribed species of *Goodia* from a nearby region in Western Australia (Thompson 2011a). However, *Paragoodia* differs from *Goodia* in its prostrate habit and few-flowered racemes. *Paragoodia* differs from *Muelleranthus* in having pinnately trifoliolate leaves, no hypanthium, relatively broad hairy pods, and seeds with a large aril.

Etymology: The genus name reflects the likely close relationship of the new genus to *Goodia* (From Latin: *para-*, beside).

Paragoodia crenulata (A.T.Lee) I.Thomps., *comb. nov.*

Muelleranthus crenulatus A.T.Lee, *Contr. New South Wales Natl. Herb.* 4(7): 418 (1973)

Type: Western Australia. Eyre District: 13 miles [21 km] S of Mt Holland, E of Hyden, 119°45′ E, 32°22′ S, *A.S.George 9441*, vii.1969; holotype: PERTH01024205; isotype: NSW590548.

Plants with scattered spreading hairs c. 1 mm long. *Stipules* narrow-ovate to lanceolate, 2.5–5 mm long, 0.6–1.5 mm wide, with midrib prominent throughout, sometimes becoming stramineous. *Leaves* to c. 40 mm long; leaflets broad-cuneate, 3–9 mm long, 3–8 mm wide, with l:w ratio c. 1; apex broadly rounded to truncate, with apiculum distinct; margin crenulate in distal third with c. 6–12 crenulations; upper surface relatively sparsely haired or glabrous, green; lower surface with secondary veins conspicuously raised. *Inflorescences* 1–3-flowered; peduncle to c. 2 cm long; a filamentous, hairy axis-terminus often extending beyond ultimate pedicel insertion; rachis to c. 15 mm long; bract c. 3 mm long, c. 1 mm wide; pedicel 2–3 mm long, usually with spreading hairs; bracteoles 3 mm long,

Key to genera in tribe Bossiaeeae

1 Leaves unifoliolate (petiole not herbaceous) or not developed; inflorescences 1- or 2-flowered with 2 to several scales below; bracts and bracteoles generally brown, chartaceous like the scales 2

1: Leaves 3–15-foliolate, or unifoliolate but then petiole herbaceous; inflorescences 1- to many-flowered, without scales below; bracts and bracteoles not brown and chartaceous 3

2 Pods winged ..... ***Platylobium***

2: Pods not winged ..... ***Bossiaea***

3 Leaves unifoliolate or 5–15-foliolate 4

3: Leaves trifoliolate 5

4 Above-ground stems to c. 5 cm long; inflorescences of solitary flowers; hypanthium shorter than calyx-tube, not striped; keel-apex rounded and ciliolate ..... ***3. Ptychosema***

4: Above-ground stems mostly 10 to 70 cm long; inflorescences few to several-flowered; hypanthium c. as long as calyx tube, striped; keel-apex angular, not ciliolate ..... ***4. Aenictophyton***

5 Leaves digitately trifoliolate; pods mostly > 3 times as long as broad; aril < 0.8 mm long ..... ***2. Muelleranthus***

5: Leaves pinnately trifoliolate (rachis sometimes very short); pods < 3 times as long as broad; aril ≥ 0.8 mm long 6

6 Erect shrubs; leaflets with margins entire; racemes several to many-flowered ..... ***Goodia***

6: Prostrate herbaceous perennials; leaflets crenulate distally; racemes 1–3-flowered ..... ***1. Paragoodia***

0.5–0.8 mm wide, inserted c. 1 mm below receptacle. *Calyx* 4–5 mm long, hairy; upper lobes fused for most of length; medial lower lobe slightly longer than lateral lower lobes; standard 8–10 mm long, c. 8 mm wide, red-brown over most of abaxial surface; wings 6 mm long, c. 2 mm wide, with auricle large, extending almost to receptacle; red-brown except near apex; keel 5.5 mm long, c. 3 mm wide, red-brown throughout; vexillary stamen less fused, sometimes becoming free; anthers c. 0.4 mm long; ovary 4-ovulate, style c. 3 mm long. *Pods*: stipe 2–3 mm long, body oblong, c. 10 mm long, 7 mm wide, rather flat, hairy; base broadly rounded, upper suture shallowly sulcate; apex obtuse to rounded, with beak 0.5 mm long; valves non-maculate. *Seeds* (only one seen) ellipsoid, 2.8 mm long, 2 mm wide, mid-brown (probably not mature colour), aril 0.8 mm long, 0.5 mm high, with lobe strongly curved.

***Specimens examined*: WESTERN AUSTRALIA** (All at type locality): *D.Bright s.n.*, 30.x.1996 (PERTH); *K.Kershow s.n.*, 8.vii.1998 (PERTH); *D.Bright & E.Bennett s.n.*, 29.x.1996 (PERTH).

Flowering period: Flowers winter.

Distribution and habitat: Known from a single locality south of Mt Holland in south-western Western Australia (Fig. 1). Grows in loam in mallee woodland.

Notes: *Paragoodia crenulata* are rare and very localised. Some features of its morphology are shown in figure 2. Images and information about this species, as *Muelleranthus crenulatus*, are presented in Lullfitz *et al.* (2008). The first few seedling leaves of *P. crenulata* are simple and crenulate *fide K.Kershaw* PERTH.

Figure 1. Distribution of *Poragoodio crenuloto* (shown by black dot; grey circle added to highlight its whereabouts).

The *Muelleranthus-Ptychosema-Aenictophyton* Group

Herbaceous perennials or *green-stemmed shrubs*, prostrate to erect, to c. 1 m high, resprouting from vertical rootstock and/or horizontal rhizomes; branches terete. *Stipules* erect, generally herbaceous at first, generally persistent. *Leaves* alternate; leaflets entire, commonly concave or folded, with base generally cuneate. *Inflorescences* not subtended by scales, terminal or pseudoaxillary (leaf-opposed), solitary or up to c. 10-flowered. Bracts and bracteoles generally persisting to flowering. *Flowers* with a hypanthium; calyx-tube equal to or shorter than lobes; upper lobes of calyx c. equal in length to lower and only a little broader, variably fused; petal markings often comprising stripes or flecks. *Pods* narrow-oblong or narrow-elliptic,

Figure 2. *Poragoodia crenuloto*, a. portion of plant with flowers and buds (*K.Kershaw s.n.* PERTH), b. pod, c. seed (b & c. *D.Bright & E.Bennett s.n.* PERTH). Scale bars: a = 10 mm, b = 2 mm, c = 0.5 mm.

glabrous, not or hardly winged. *Aril* small or absent.

Notes: The petal markings in this group have two components, one that gives a red colour (reddish when petal dry) and the other which produces a purple-brown colour (purple when dried). The red pigmentation is commonly present each side of the throat of the standard flare and also at the apex of the keel. Microscopic examination shows this colour to be uniformly infused in the petal tissue. The purple-brown pigmentation is more widely distributed, and is commonly extensive over the abaxial surface of the standard. It can be present on all petals and is responsible for the characteristic stripes and flecks seen in petals of species in this group. Microscopic examination shows that this marking is created by minute densely pigmented dots.

2. *Muelleranthus* Hutch., *Gen. Fl. Pl.* 1: 361 (1964)

Type: *M. trifoliolatus* (F.Muell.) Hutch. ex A.T.Lee

Prostrate herbaceous perennials, to c. 3 cm high, with a vertical rootstock (unknown if horizontal rhizome present); above-ground parts glabrous or variously pubescent; stems to c. 60 cm long, to c. 1 mm in diameter. *Stipules* broad-ovate to lanceolate, slightly fleshy, green. *Leaves* digitately 3-foliolate, to c. 40 mm long, petiole slender, not herbaceous, longer than the leaflets; leaflets broad-cuneate, obcordate or obovate, flat, concave or conduplicate, somewhat fleshy; upper surface gland-dotted; lower surface with secondary veins generally not raised. *Inflorescences* pseudoaxillary (leaf-opposed), determinate, 1–3-flowered; bracts and bracteoles generally persistent; bracteoles inserted distally on pedicel. *Flower-buds* with a rounded apex; hypanthium short, obconical, generally with raised nerves; hypanthium and calyx lacking longitudinal stripes; calyx-lobes equal to or longer than tube, with apices not filiform; upper lobes fused for ½ or more of length; lower lobes oblong-ovate; standard shorter than, equal to or longer than other petals; wings equal to or shorter than keel; standard with red-brown markings only, wings and keel variously marked red-brown; keel-apex c. rounded, sometimes marked red; anther connective moderately broad; ovary 5–12-ovulate; stigma small. *Pods* with stipe mostly shorter than calyx; body generally narrow-oblong in profile, rarely minutely winged, with a beak to c. 1 mm long; valves sometimes maculate. *Seeds*: aril small, with lobe strongly curved, or not developed.

2a. *Muelleranthus trifoliolatus* (F.Muell.) Hutch. ex A.T.Lee, *Contr. New South Wales Natl. Herb.* 4(7): 418 (1973)

Ptychosema trifoliolatum F.Muell., *S. Sci. Rec.* 2: 72 (1882).

Type: Western Australia. Upper Murchison River, *Gale*, 1881; holotype: MEL26470.

Plants with sparse to scattered appressed or occasionally spreading hairs c. 0.3 mm long. *Stipules* narrow-ovate to broad-ovate or c. orbicular, 2–5 mm long, 1.5–4 mm wide, with midrib generally distinct. *Leaves*: lamina of leaflets cuneate to obcordate, 2–8 mm long, 2–8 mm wide, with l:w ratio 0.8–1.2; apex truncate, retuse or bilobed, with apiculum absent or minute; margin entire; upper surface green, sometimes with glands dark, glabrous or hairy; lower surface with secondary veins often faintly evident. *Inflorescences* 1, 2- or rarely 3-flowered; peduncle to 3.5 cm long; bract 2–4 mm long, 1–2 mm wide; pedicel 1.5–5 mm long, with spreading hairs; bracteoles 2–3 mm long, 0.7–1 mm wide, inserted c. 1 mm below receptacle. *Hypanthium* 0.5–1 mm long; calyx 3–5.5 mm long, glabrous, with lobes slightly longer than tube; upper lobes fused for most of length; standard 8–15 mm long, 8–12 mm wide, with flare broad, not or only slightly red-brown beyond flare abaxially; wings 7–12 mm long, 2–3 mm wide, variably red-brown in proximal ⅔, yellow apically; keel 7–12 mm long, 3.5–5 mm wide, patchily to entirely red-brown, generally with a distinct red apex (drying pink); anthers c. 0.5 mm long; ovary 8–12-ovulate, style c. 3 mm long. *Pods*: stipe 2–3 mm long, body narrow-oblong, 15–25 mm long, 3.5–5.5 mm wide; upper suture not winged; valves usually with dark red-brown blotches. *Seeds* ellipsoid, 2–2.5 mm long, red-brown, mottled blackish; aril 0.2 mm long, 0.2 mm high, with aril-lobe curved.

***Selected specimens of c. 40 examined*: WESTERN AUSTRALIA**: W of homestead, Mt Narryer Station, *A.S.George 17553*, 19.viii.1999 (CANB, DNA, PERTH); c. 43 km NW of Belele Homestead, *N.H.Speck 646*, 5.ix.1957 (CANB, PERTH); 13 km W of

Meekatharra, *N.H.Speck 598*, 4.ix.1957 (CANB, PERTH); Murgoo Station, NE of Mullewa, *A.M.Ashby 2547*, 17.viii.1968 (PERTH); Whalloo Rocks, Coodardy Station, NW of Cue, *A.R.Main*, 12.ix.1968 (PERTH); Gascoyne R., Junta Junta, *C.A.Gardner 6090*, 21.ix.1941 (PERTH); c. 46 km W of Mt Magnet, *A.S.George 7963*, 11.ix.1966 (PERTH); Nallan, N of Cue, *C.A.Gardner 7833*, 6.x.1943 (PERTH); Ballan Rock near Mt Magnet, *R.Bates 3987*, 1.ix.1984 (PERTH); 2 km NNE of Randall Bore, Yarlarweelor Station, *R.J.Cranfield 5592*, 10.viii.1986 (PERTH); SW of Mt Gould, boundary Shire of Murchison, *A.E.de Jong 80334.2*, 5.viii.1992 (PERTH); Mullewa–Carnarvon Rd at 63.3 km S of turnoff to Glenburgh homestead, just S of No. 16 well, *S.Patrick & A.Cochrane 3665*, 10.viii.2000 (PERTH); 17 km N of road junction of Murgoo, Wooleen and Boolardy Rds, *A.M.Ashby 5046* (AD); 6.4 km S of Bore no. 3, Talisker Station, Carnarvon Botanical District, *R.J.Chinnock 6748*, 15.viii.1986 (AD, BRI, PERTH); Boolardy Station, Murchison River, *C.A.Gardner*, 30.vii.1927 (PERTH).

***Flowering period*:** Flowers mostly winter–spring.

***Distribution and habitat*:** Occurs largely inland in north-western Western Australia (Fig. 3). Grows in red sand in Mulga woodland and scrub.

***Notes*:** *Muelleronthus trifoliolotus* is sympatric with *M. obovatus*, and mixed collections have been recorded from Boolardy Station (*Gordner* PERTH). Flowers, a leaf and a pod of *M. trifoliolotus* are shown in figure 4e–g. Specimens from the Mt Magnet area are smaller in most parts; especially the leaves.

The circumscription of *M. trifoliolatus* has been markedly altered in this revision compared to that of Lee (1973), with *M. porvolotus* and *M. obovatus* segregated as new species and several specimens reassigned to *M. stipuloris*. Consequently the distribution of *M. trifoliolotus* is now far more restricted than that described in recent floras.

A sheet bearing *M. trifoliolotus*, MEL 26471, was cited as an isotype by Lee (1973); however, there is no evidence that this material was collected by Gale.

2b. *Muelleranthus obovatus* **l.Thomps.**, *sp. nov.*

A M. trifoliolato *(F.Muell.) Hutch. ex A.T.Lee foliolis et stipulis ongustioribus, foliolis obovatis, floribus minoribus, leguminibus brevioribus 4–5-seminalis differt.*

***Type*:** Western Australia. Peak Bore, *T.L.Setter 353*, 16.ix.1973; holotype: PERTH06378307; isotype: AD.

Plonts with very few, mostly appressed hairs 0.2–0.3 mm long. *Stipules* narrow-ovate to lanceolate, 1.5–4 mm long, 0.7–2 mm wide, with midrib generally distinct. *Leaves*: lamina of leaflets cuneate-obovate to obovate, or occasionally cuneate, 3–10 mm long, 1.5–6 mm wide, with l:w ratio mostly 1.2–2.2, apex broadly rounded to truncate, less often slightly retuse, with apiculum minute or absent; margin entire; upper surface green, commonly glabrous; lower surface with secondary veins not evident. *Inflorescences* 1(or 2)-flowered; peduncle to 4 cm long; bract 2–3 mm long, 0.5 mm wide; pedicel 4–6 mm long, with spreading hairs; bracteoles 1–2 mm long, 0.2–0.5 mm wide, inserted 1–2 mm below receptacle. *Hypanthium* c. 0.5 mm long; calyx 2–3 mm long, glabrous, with lobes c. equal to tube; upper lobes fused for most of length; standard 4–6 mm long, c. 5 mm wide, with flare moderately broad, abaxially variably red-brown; wings 3–5 mm long, 1–1.5 mm wide, yellow, sometimes red-brown centrally; keel 4–6 mm long, 2.5 mm wide, pale throughout or flecked red-brown; anthers 0.3–0.4 mm long; ovary 5- or 6-ovulate, style 1–1.5 mm long. *Pods*: stipe 2–4 mm long, body narrow-oblong, 10–17 mm long, 4–5 mm wide; upper suture commonly thinly and

Key to species of *Muelleranthus*

1 Wings red-brown throughout (purple when dry) or at least distally; aril absent; standard 4–5 mm long ..... **2d. *M. stipularis***

1: Wings yellow throughout or at least distally; aril present; standard 4–15 mm long **2**

2 Wings 3–5 mm shorter than keel; standard shorter than keel, with adaxial flare c. 0.3 mm wide; pedicels glabrous or with few appressed hairs ..... **2c. *M. parvalatus***

2: Wings 0–1 mm shorter than keel; standard equal to or longer than keel, with adaxial flare c. 1 mm wide; pedicels bristly with spreading hairs **3**

3 Keel 4–6 mm long; pods 4–6-seeded, usually lacking macules, often slightly winged along upper suture; leaflet-lamina longer than broad, with apex mostly rounded or rounded-truncate ..... **2b. *M. obovatus***

3: Keel 7–12 mm long; pods mostly 7–10-seeded, usually conspicuously maculate, not winged; leaflet-lamina c. as broad as long, with apex mostly truncate or truncate-emarginate ..... **2a. *M. trifaliolatus***

minutely winged; valves lacking red-brown blotches or rarely a few blotches evident. *Seeds* (not seen mature), ellipsoid, c. 2.5 mm long, red-brown when semi-mature; aril 0.2 mm long, 0.2 mm high, with aril-lobe curved.

***Selected specimens of 10 examined*: WESTERN AUSTRALIA:** ExSB 113, Pongo Paddock, Towera Station, 23°10 115°15, *R.J.Cranfield 1815*, 6.viii.1981 (PERTH); Boolardy station, *A.W.Humphries*, 21.ix.1950 (PERTH); 2 km NE of Towrana Homestead, *R.J.Cranfield 2184*, 30.iv.1982 (PERTH); 1.5 km E of Middle Blue Hills, well, Milly Milly Station, *R.J.Cranfield 5335*, 24.iv.1986 (PERTH); 9 km 5SE of Meegea Hill, Milly Milly Station, *R.J.Cranfield 9753*, 9.v.1995 (CANB, PERTH); Boolardy Station, Murchison River, *C.A.Gardner*, 30.vii.1927 (PERTH).

***Flowering period*:** Flowers autumn, winter and early spring.

***Distribution and habitat*:** Occurs in far north-western Western Australia (Fig. 3). Grows in sandy soils in open woodland.

***Etymology*:** The epithet refers to the typical shape of the leaflets (From Latin: *obovatus*, obovate).

***Notes*:** *Muelleranthus obovatus* is distinguished from other species of the genus by its leaflets which are obovate with a relatively high length to width ratio and a rounded apex (Fig. 4a–b), and its long pedicels. The absolute and relative length of the petals are also diagnostic (Fig. 4c). Compared to *M. trifoliolatus*, with which it is sympatric, it also has narrower stipules, bracts and bracteoles, smaller flowers and shorter and fewer-seeded pods with valves generally lacking red-brown blotches (Fig. 4d). Although the valves of the pod are not generally maculate, a rudimentary wing above the sutural nerve often has red-brown streaks. *Muelleranthus obovatus* and *M. trifoliolatus* have a similar indumentum including a distinctive patch of spreading hairs on the pedicels.

2c. *Muelleranthus parvalatus* **I.Thomps.**, *sp. nov.*

A M. trifoliolato *(F.Muell.) Hutch. ex A.T.Lee stipulis angustioribus, pilis pedicellorum appressis, vexillo breviore, alis minoribus comparate luteis magnopere differt.*

***Type*:** Northern Territory. Near Chilla Wells Bore, Tanami Desert Wildlife sanctuary, Tanami Track, c. 390 km NW of Alice Springs, *A.C.Beauglehole 50485*, 16.v.1976; holotype: MEL2100375; isotype: DNA169493.

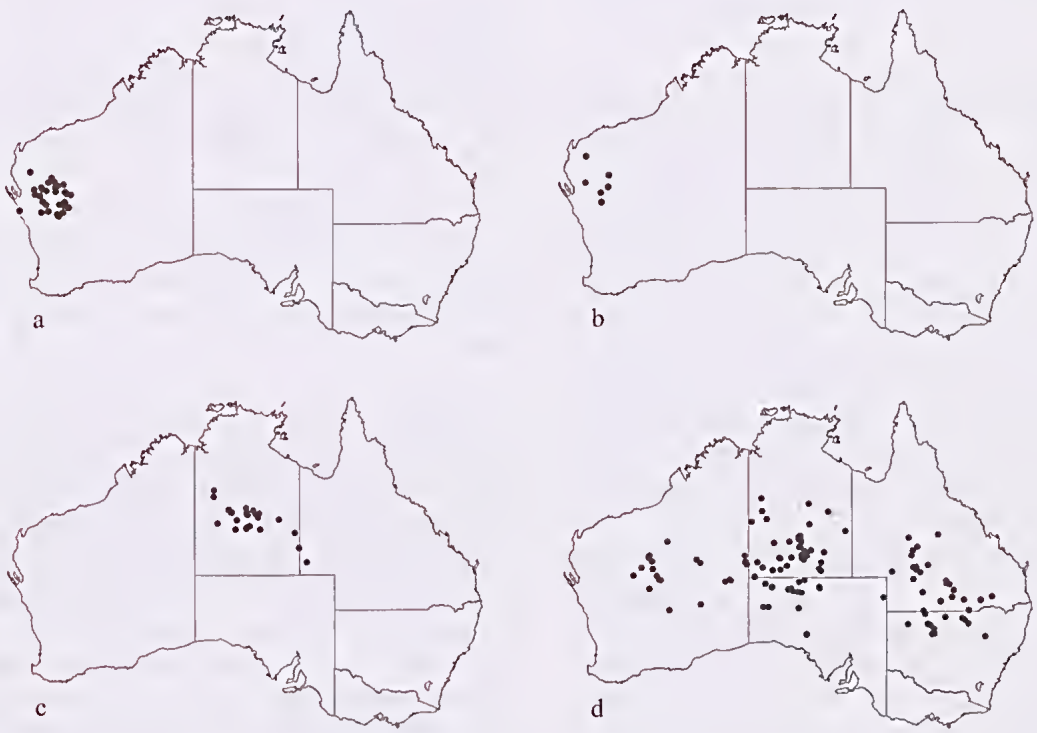

Figure 3. Distributions of a. *Muelleranthus trifalialatus*, b. *M. abavatus*, c. *M. parvalatus*, and d. *M. stipularis*.

Plants very sparsely haired with appressed hairs c. 0.2 mm long. *Stipules* narrow-ovate to lanceolate, 1.5–3 mm long, 0.5–1.5 mm wide, with midrib generally distinct. *Leaves*: lamina of leaflets cuneate-obovate or obcordate, 3–6 mm long, 2–5 mm wide, with l:w ratio 1–1.4; apex truncate, retuse or bilobed, not apiculate; upper surface sometimes with dark glands, glabrous; lower surface with secondary veins not evident. *Inflorescences* 1(or 2)-flowered; peduncle 1–3 cm long; bract 1–2 mm long, 0.7 mm wide; pedicel 1–3 mm long, glabrous or with appressed hairs; bracteoles 1–2 mm long, 0.3 mm wide, inserted c. 1 mm below receptacle. *Hypanthium* c. 0.5 mm long; calyx 3–4 mm long, glabrous, with lobes longer than tube; upper lobes fused for c. half of length; sta ndard 6–10 mm long, 6–8 mm wide, with flare narrow, usually flecked red-brown abaxially; wings 4.5–7 mm long, 1.5–2 mm wide, all yellow or with a red-brown patch proximally; keel 7–12 mm long, 4–5 mm wide, usually with red-brown flecks throughout; anthers c. 0.6 mm long; ovary 8–12-ovulate, style 2.5–3 mm long. *Pods*: stipe 2–3 mm long, body narrow-oblong, 15–25 mm long, 3.5–4.5 mm wide; upper sutures not winged; valves sometimes faintly spotted. *Seeds* irregularly ellipsoid, 2–2.8 mm long, red-brown, sometimes lightly mottled, aril minute but with lobe distinct.

***Selected specimens of c. 20 examined*: NORTHERN TERRITORY**: Curlew Waterhole, Lander R., c. 100 km NW of Willowra homestead, *G.Chippendale 4805*, 31.vii.1958 (AD, CANB, DNA, NSW, PERTH); c. 3 km E of Wycliffe Creek crossing, Stuart Hwy, *D.J.Nelson 692*, 30.iv.1963 (AD, CANB, DNA, NSW); 7 km WSW No. 3 Bore, Manners Creek Station, *D.E.Albrecht 6318*, 21.iii.1995 (DNA, MEL279975); Stirling Swamp, *P.K.Latz 5605*, 3.vii.1974 (CANB, BRI, DNA); 10 km from Warrabri Aboriginal Settlement towards "Murray Downs", *N.Ollerenshaw 575*, 27.i.1982 (CANB); Around Parnta outstation, 35 km S of Lajamanu, *K.G.Brennan 6007*, 10.x.2003 (DNA). **QUEENSLAND**: Mulligans River, *W.A.Cornish*, 1885 (MEL26469).

Flowering period: Flowers most times of year in response to rainfall.

Distribution and habitat: Occurs in the Northern Territory and in far south-western Queensland (Fig. 3). Grows adjacent to watercourses and swamps.

Etymology: The epithet refers to the relatively small wing petals (From Latin: *parvus*, small and *alatus*, winged).

Notes: The keel of *M. parvalatus*, and to a lesser extent the standard, are distinctively speckled purple-brown, and the wings are relatively short and entirely or mostly yellow (Fig. 4j). The standard claw is conspicuously cuneate as is the limb. *Muelleranthus parvalatus* is similar to *M. trifoliolatus* but, in addition to the differences indicated in the key, has a lower proportion of 2-flowered racemes, shorter pedicels, and pod valves that lack maculations. Glabrous forms of *M. stipularis* vegetatively resemble *M. parvalatus*. *Muelleranthus parvalatus* can be distinguished in the fruiting period by the persistent style and stamens, which are shorter.

Muelleranthus trifoliolatus, *M. obovatus* and *M. parvalatus* form a group based on similarities in floral structure and aril development. The seed of *M. parvalatus* is shown in figure 4k and habit is shown in figure 4i.

The illustrations and much of the description of *M. trifoliolatus* in *Flora of Central Australia* (Crisp 1981) correspond to *M. parvalatus*.

2d. *Muelleranthus stipularis* (J.M.Black) A.T.Lee, *Contr. New South Wales Natl. Herb.* 4(7): 418 (1973)

Ptychosema stipulare J.M.Black, *Trans. Roy. Soc. South Australia* 62(1): 103 (1938).

Type: Northern Territory. Bundooma, *J.B.Cleland*, 8.viii.1936; holotype: AD97221313; isotype: AD95830040, MEL26465, K000278104, image seen online.

Muelleranthus trifoliolatus sensu A.T.Lee, *Contr. New South Wales Natl. Herb.* 4(7): 418 (1973), *pro parte*; *sensu* T.A.James (1991, 2002 revised edn), as *M. trifoliatus*, in G.J.Harden (ed.), *Fl. New South Wales* 2: 511–512, *pro parte*.

Prostrate to weakly erect plants with a dense indumentum of spreading or subappressed hairs to c. 1 mm long, or with a sparse to scattered indumentum of appressed hairs 0.3–0.7 mm long, or plants quite glabrous. *Stipules* narrow-ovate to broad-ovate, elliptic or c. orbicular, 2–6 mm long, 1–6 mm wide, with abaxial venation generally indistinct, usually with 2 or more veins evident proximally. *Leaves*: lamina of leaflets cuneate, slightly obcordate or obovate, 2–10 mm long, 2–7 mm wide, with l:w ratio 1–1.7; apex broadly rounded, truncate or slightly retuse, apiculum absent or small;

margin entire; upper surface often reddish, hairy or less often glabrous; lower surface with secondary veins not evident. *Inflorescences* 1(or 2)-flowered; peduncle to 5 cm long; bract 2–4 mm long, 0.5–1 mm wide; pedicel 1–2.5 mm long; bracteoles 1–3 mm long, 0.2–0.6 mm wide, inserted c. 0.5 mm below receptacle. *Hypanthium* c. 0.5 mm long; calyx 3–4 mm long, glabrous or hairy, with lobes equal to or longer than tube; upper lobes fused for c. half of length; standard 4–6 mm long, c. 5 mm wide, adaxially red-brown, abaxially red-brown or speckled red-brown but pale along nerves; wings 3–4 mm long, c. 1 mm wide, entirely red-brown; keel 4–7 mm long, 2–2.5 mm wide, greenish-yellow; anthers 0.3 mm long; ovary 4–10-ovulate, style 1–2 mm long. *Pods*: stipe 2–3 mm long, body narrow-oblong or narrow oblong-elliptic, 17–30 mm long, 5–7 mm wide, upper suture not winged; valves occasionally with a few dark red-brown blotches. *Seeds* ellipsoid to globular, 2–3 mm long, brown, often complexly mottled cream-yellow and/or blackish; aril not developed.

***Selected specimens of c. 50 examined*: WESTERN AUSTRALIA: subglabrous form:** 120 km N of Meekatharra, *D.E.Symon 9984*, 15.v.1975 (AD, CAN8, NSW, PERTH); Little Sandy Desert, 7.4 km ENE of Cooma Well, 43.6 km NNW of Yanneri Lake, *S. van Leeuwen 3152*, 13.viii.1997 (8RI, MEL2308777, PERTH); 8elow trig point M6, southern Carnarvon Range, Little Sandy Desert, *K.F.Kenneally & D.J.Edinger K 12224 E 2689*, 6.viii.2001 (PERTH); c. 147 km NE of Wiluna, *A.S.George 5602*, 28.vii.1963 (PERTH); Plot 311, Lorna Glen, *T.8ragg 2004-31*, 11.viii.2004 (PERTH); 19.9. km SE of Yanneri Lake, Great Sandy Desert, *S.van Leeuwen 4967*, 18.viii.2001 (8RI, PERTH); Sir Frederick Range, *D.Symon 2306*, 1.viii.1962 (AD); **glabrous form:** Near Mt Squires, 8arrow Range, *R.Helms*, viii.1891 (MEL). **NORTHERN TERRITORY: glabrous or sparsely haired form:** 30 km ESE of Neutral Junction Homestead, *D.E.Albrecht & P.K.Lotz 12762*, 27.ii.2009 (DNA); 81 km S of Hookers Creek settlement, *G.Chippendole 2296*, 13.vii.19S6 (AD, DNA); **hairy form:** 8onny Creek, 80.S km S of Tennant Creek, *N.Wolker*, 23.viii.1966 (AD); 8 km NE of Angas Downs on road to Wallara Ranch, *8.G.8riggs 7164*, 30.ix.1979 (NSW). **SOUTH AUSTRALIA: hairy form:** Mt Sarah Station, Lake Eyre region, *R.J.Bates 51194*, 30.ix.1998 (AD); 0.8 km SE of Mt Finke trig., *D.E.Symon 1262*, 7.x.1987 (AD); Mt Kintore sandhills, *R.Botes 58210*, 27.iv.2001 (AD); c. 2 km N of Marla, *P.J.Lang, P.D.Canty & A.C.Robinson BSOP-468*, 22.v.2000 (AD); Everard Ranges, *A.G.Spooner 108*, 10.ix.1968 (AD, NSW). **QUEENSLAND: hairy form:** c. 10 km W of Moonie, *L.Pedley 1051*, 18.ix.1962 (8RI); 69 km NE of Aramac, *E.J.Thompson GAL356*, 22.iii.2000 (AD, BRI, NSW); "Top Crossing" c. 30 km S of Winton, *K.P.Nicolson 387*, 20.viii.1988 (8RI); Currawinya National Park, boundary track S of Salt 8ore, *P.I.Forster 20534 & M.Watson*, 21.iii.1997 (8RI, MEL2496S9, NSW); Idalia National Park, Reedy Springs W of 8ulloo R., *P.I.Forster 18871 & T.Ryon & C.Morgan*, 14.iii.1996 (8RI); **glabrous form:** 1S km S of Charleville along road to Wyandra, *R.W.Purdie & D.E.8oylond 236*, 26.iii.1976 (BRI); 89.6 km W of St George, *A.R.Bean 25502*, 26.viii.2006 (8RI); c. 38 km SE of Charleville on road to 8ollon, *B.J.Lepschi & A.V.Slee 1105*, 12.x.1993 (CAN8); c. S8 km W of Roma, *N.C.W.8eodle*, 1S.v.1963 (NSW). **NEW SOUTH WALES: hairy form:** Kurrajong Station near Glengarry Opalfield, c. 100 km NE of Brewarrina, *J.Thompson 2110*, 3.ix.1974 (NSW); 1.8 km N of Cumborah towards Lightning Ridge, *A.R.8ean 22914*, 14.ix.2004 (8RI); 16 km W of Tundulya, 37 km S of Louth, *J.Pickard 2012*, 22.iii.1973 (NSW); **glabrous form:** Pulpulla near Cobar, *H.Andra*, 188S (MEL).

***Flowering period*:** Flowers at various times depending on rainfall.

***Distribution and habitat*:** Occurs in central and eastern Western Australia, the Northern Territory, western Queensland and north-western New South Wales (Fig. 3). Grows in sandy soils in woodland and grassland.

***Notes*:** *Muelleranthus stipularis* is distinguished by the short petals with a distinctive colour pattern and the lack of an aril on the seed (Fig. 4l–m). Plants are often but not always conspicuously hairy with spreading hairs, and have large rotund stipules. Such plants are immediately identifiable as *M. stipularis*.

Most of the glabrous collections are from the Maranoa and Warrego districts of southern Queensland. In Queensland, plants generally have longer bracts, bracteoles and pods, and pods generally contain more seeds. In New South Wales a few specimens have a moderately dense indumentum of short appressed hairs. In north-central Western Australia a form with a very sparse indumentum of appressed hairs predominates, and leaflets of this form are usually relatively small.

A sparsely haired specimen from the Northern Territory (*D.E.Albrecht & P.K.Latz 12762* DNA); is somewhat distinctive in its combination of stouter branches, more erect habit, large leaflets, slender stipules, and a relatively long keel. Further investigation is needed to determine if it warrants taxonomic recognition.

Muelleranthus stipularis is the most widespread species in the genus. Its distribution overlaps that of

Figure 4. *Muelleranthus*. a–d. *M. obavatus*: a. partian *af* holotype (*T.L.Setter 353* PERTH), b. leaf (*R.J.Cranfield 9753* PERTH), c. flower, d. pod (c. & d. *R.J.Cranfield 1815* PERTH). e–h. *M. trifalialatus*, e. leaf (*B.Maslin 5176* PERTH), f. inflarescence (*S.J.J.Davies s.n.* PERTH), g. flower (*S.Graham 5* PERTH), h. pod (*H.Demarz D5679* PERTH). i–k. *M. parvalatus*, i. habit, j. flower (i & j. *I.D.Cowie & P.S.Brocklehurst 10235* DNA), k. seed (*Hill 306* MEL). l–m. *M. stipularis*, l. flower (*P.Martensz 2734* CANB), m. seed (*J.Maconochie 1388 CANB*). Scale bars: a, i = 10 mm, b, c, e–g, j, l = 2 mm, d, h = 5 mm, k, m = 0.5 mm.

M. parvalatus in central Australia and *M. trifoliolatus* in central Western Australia. Lee (1973) placed specimens of *M. stipularis* with a sparse indumentum from Queensland, New South Wales and the Northern Territory in *M. trifoliolatus*, and this has subsequently caused some confusion in identification.

Lee (1973) incorrectly designated AD 95830040 as the holotype of *P. anomalum*. This material came from the herbarium of the collector J.B. Cleland and was unlikely to have been used by Black when describing the new species. Lee appears not to have been aware of the existence of the material used by Black which is now mounted on sheet AD 97221313.

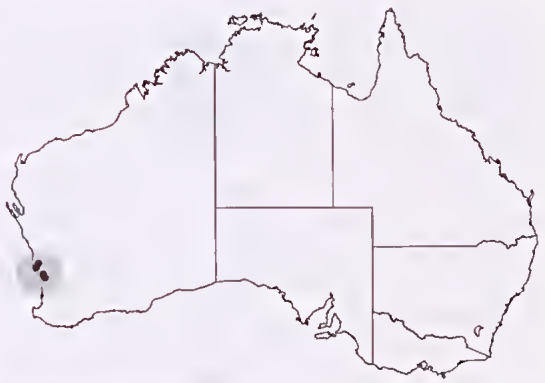

Figure 5. Distribution of *Ptychosema pusillum* (shown by black dots; grey circle added to highlight their whereabouts).

3. *Ptychosema* Benth., *in* J.Lindley, *Edwards's Bot. Reg.*, app. to vols 1–23, xvi (1839)

Type: *P. pusillum* Benth.

Dwarf herbaceous perennials to c. 8 cm high, with underground stems rising vertically from deep horizontal rhizomes; above-ground parts sparsely pubescent; branches to c. 0.7 mm in diameter. *Stipules* narrow-lanceolate, fleshy, green. *Leaves* imparipinnate, with petiole and rachis sub-herbaceous, not fleshy; petiole generally longer than leaflets but shorter than rachis; leaflets generally much longer than broad; upper surface not dotted with glands; lower surface with secondary veins raised. *Inflorescences* of a solitary terminal flower; a rudimentary axis-terminus sometimes evident opposite bract; bract and bracteoles persistent; bracteoles inserted c. mid-pedicel or more distally. *Flower-buds* not or only minutely pointed at apex; hypanthium obconical, with nerves obscure; hypanthium and calyx not striped; calyx-lobes c. equal to tube, with apices often shortly filiform; upper lobes fused for most of length; lower lobes ±triangular; standard clearly longer than wings, wings longer than keel; standard with red-brown stripes abaxially, wings and keel variously marked reddish; keel c. rounded at apex; anther connective slender; ovary glabrous, ovules per ovary unknown; stigma large. Pods and seeds unknown.

Notes: There have been three taxa included with *P. pusillum* in *Ptychosema* since the genus was erected. Two of these, *Ptychosema trifoliolatum* and *P. stipulare*, were transferred to *Muelleranthus* in 1973, while in this paper *P. anomalum* is transferred to *Aenictophyton*. Thus, *P. pusillum* has been returned to its original status as a monotypic genus. *Ptychosema* is likely to be most closely related to *Aenictophyton* based on the herbaceous petiole and rachis of the leaves and its growth from deep horizontal rhizomes. The last of these characters has not been recorded in *Muelleranthus* and *Paragoodia*, but there is insufficient knowlege of underground parts of these genera to rule out their presence.

Ptychosema pusillum Benth., *in* J.Lindley, *Edwards's Bot. Reg.*, app. to vols 1–23, xvi (1839)

Type: Western Australia. Swan River, *J.Drummond s.n.*; holotype: K000278107 *n.v.*, image seen in Kew herbarium catalogue on-line.

Plants to c. 3 cm high excluding inflorescences, with scattered appressed or spreading coarse hairs mostly 0.5–1 mm long; stems to c. 0.7 mm in diameter. *Stipules* narrow-lanceolate to linear, 1–2.5 mm long, 0.1–0.4 mm wide. *Leaves* 5–13-foliolate, to c. 40 mm long; petiole 5–10 mm long, not thicker than pulvinus; rachis slightly green, 0.3–0.4 mm in diameter, not fleshy; leaflets occasionally sub-opposite, obovate to narrow-oblanceolate, narrow-cuneate or appearing narrow-oblong to linear when folded, 4–10 mm long; upper surface glabrous; lower surface with secondary veins conspicuously raised. *Flowers* solitary; peduncle 20–50 mm long; bract narrow-ovate, 2 mm long, c. 1 mm wide; pedicels 10–12 mm long; bracteoles c. 2

Figure 6. *Ptychosema pusillum* (*A.P.Brown 1013* PERTH). Actual size

mm long, 0.5–0.8 mm wide, inserted 3–8 mm below receptacle. *Hypanthium* obconical, 1–1.5 mm long; calyx 5–6 mm long, with appressed hairs; lobes c. as long as tube; upper lobes fused for most of length forming a truncate upper lip with laterally directed filiform points; lower lobes with filiform apices; standard 10–18 mm long, c. 10–18 mm wide, with a moderately broad flare, red-brown abaxially except for nerves, wings 8–12 mm long, c. 3 mm wide, with limb decurved, entirely reddish, keel 7–10 mm long, c. 3.5 mm wide, red-brown streaks not quite extending to a green apex, densely ciliolate apically; anthers 0.5 mm long; style c. 1 mm long, stigma very large. *Pods and seeds* not seen.

Specimens examined: **WESTERN AUSTRALIA**. Near Badgingarra, *E.A.Griffin*, date unknown (PERTH03510263); Lake Guraga, *A.P.Brown 1013*, 30.viii.1992 (PERTH); Beerera NR, *G.Keighery*, 5.x.2010 (MEL); Locality unknown, *J.B.Cleland 190*, c. 1912-13 (NSW).

Flowering period: Flowers late winter–spring.

Distribution and habitat: Occurs in the Badgingarra region a few hundred kilometres north of Perth in far western Western Australia (Fig. 5). Grows in pale sands in heathy woodland.

Notes: A rare, colony-forming species with numerous small above-ground tufts arising via vertical stems from deep horizontal rhizomes. Flowers are held well above the leaves. Leaflets show some resemblance to those of *Paragoodia crenulata* in terms of apiculum size, raised abaxial venation and an indumentum of scattered long spreading hairs. An image of *P. pusillum* is shown in figure 6. Distinctive floral features of *P. pusillum* include the ciliolate apex of the keel, downcurved wings, and a very large stigma. The shape of the ovary suggests that the pod would be similar to those in *Muelleranthus* and *Aenictophyton*.

4. *Aenictophyton* A.T.Lee, *Contr. New South Wales Natl. Herb.* 4(7): 422 (1973)

Type: *A. reconditum* A.T.Lee

Erect or sprawling herbaceous perennials or green-stemmed shrubs to c. 80 cm high, with stems rising from deep horizontal rhizomes; above-ground parts glabrous or with a short pubescence; branches to c. 3 mm in diameter. *Stipules* lanceolate, fleshy, green or soon stramineous. *Leaves* unifoliolate or imparipinnate, sometimes caducous, petiole (and rachis if imparipinnate) stout and green (resembling branches) beyond pulvinus; leaflets mostly much longer than broad; upper surface not gland-dotted; lower surface with secondary veins generally slightly raised. *Inflorescences* of terminal, indeterminate, pedunculate

Key to species of *Aenictophyton*

1	Leaves 5–15-foliolate	4a. ***A. anomalum***
1:	Leaves unifoliolate	4b. ***A. reconditum***

racemes; primary raceme mostly several-flowered; secondary racemes shorter, fewer-flowered; flowers developing progressively; bract and bracteoles variably persistent; bracteoles inserted proximally to distally on pedicel. *Flower-buds* with apex pointed; hypanthium c. cylindrical, with nerves raised; hypanthium and calyx red-striped longitudinally; calyx-lobes c. equal to or longer than tube, subulate; upper lobes fused for ⅓ to ½ of length; lower lobes triangular; standard and wings slightly longer than keel; standard with red-brown stripes abaxially, wings and keel variously streaked reddish; keel c. right angled between apex and upper margin; anther connective slender; ovary 6–10-ovulate; stigma small. *Pods* with stipe subequal to or longer than calyx; body elliptic or oblong-elliptic in profile, lacking pigmented patches. *Seeds*: aril small, with lobe slightly to moderately curved or rudimentary.

Notes: *Aenictophyton* is a genus of two species extending from far north-western Australia ESE through central Australia and into far north-western New South Wales. The genus is characterised by a shrubby habit, terminal, several-flowered indeterminate inflorescences, a long cylindrical hypanthium, a striped hypanthium and calyx, and a keel with an angular apex. Its closest relative is likely to be *Ptychosema* q.v.

4a. *Aenictophyton anomalum* (F.Muell.) I.Thomps., *comb. nov.*

Ptychosema onomolum F.Muell., *Frogm.* 9: 62 (1875)

Type: Northern Territory. Mt Olga, *E.Giles*, 1873–4; lectotype: MEL26461, *fide* A.T.Lee, *Contr. New South Wales Notl. Herb.* 4(7): 416 (1973); isolectotype: MEL26462.

Plants to c. 30 cm high, with fine appressed or spreading hairs 0.2–0.5 mm long. *Stipules* lanceolate, mostly 1–2 mm long, 0.4–0.8 mm wide, to 4 mm long on lower stems, herbaceous. *Leaves* mostly 7–15-foliolate, to c. 50 mm long; petiole base pulvinate, most of petiole and rachis herbaceous, fleshy, branch-like; leaflets opposite or occasionally a small proportion alternate, elliptic, broad-elliptic, obovate or cuneate, narrow-oblong to c. linear when folded, 2–10 mm long; apex rounded to truncate, apiculate; upper surface green, variably glabrescent. *Primory inflorescences* few to several-flowered; bract 1–2.5 mm long; pedicels 2–4 mm long, not green, hairy, becoming recurved; bracteoles 0.8–2 mm long, 0.2–0.3 mm wide, inserted 1–2 mm below receptacle. *Hyponthium* 1.5–3 mm long; calyx 3–4.5 mm long, with a sparse indumentum of short appressed hairs; lobes shorter than tube; standard 7–9 mm long, 6–7 mm wide; wings 5–9 mm long, c. 2 mm wide; keel 5–7 mm long, c. 3 mm wide; anthers c. 0.3 mm long; style c. 2 mm long. *Pods* with stipe equal to or shortly exceeding calyx; body elliptic, 10–20 mm long, 4–6 mm wide, sometimes with red-brown blotches or speckles, mostly 1- or 2-seeded. *Seeds* 3 mm long; aril minute, with a vestigial lobe.

Selected specimens of c. 30 examined: **WESTERN AUSTRALIA:** Walter James Range, road to Tjukurla, *H.P.Vonow 3114 & V.T.Clarke* (AD, PERTH). **NORTHERN TERRITORY:** 27 km E of Docker Settlement, *J.R.Maconochie 1849*, 26.viii.1973 (AD, BRI, CANB, MEL209332B, NSW, PERTH); c. 3 km NE of Ayers Rock, *N.M.Henry 469* (AD, DNA, MEL2093327, PERTH); 7 km SW of Reedy Rockhole, *P.K.Latz 8772*, 13.viii19B1 (CANB, DNA). **SOUTH AUSTRALIA:** Birksgate Range, near Atuti Hill, W of Mt Lindsay, *P.D.Canty 8523-39296* (AD). **NEW SOUTH WALES:** 'Nulty Springs', Enngonia, c. 60 km NE of Bourke, *G.M.Cunningham & P.L.Milthorpe 4165*, 20.xi.1975 (NSW); 'Burrawantie', *W.E.Mulham 1107*, 1B.viii.1977 (CANB, NSW); c. 6 km NE of Cumborah on Lightning Ridge Rd, *G.M.Cunningham & P.Mulham 1962*, 17.iii.1974 (NSW); Lednapper Crossing Rd, 900 m from 'Beulah' entrance towards Bourke, *B.A.Bell 128 & S.Donaldson*, 29.ix.1999 (CANB).

Flowering period: Flowers late winter to spring.

Distribution and habitat: Occurs in two widely disjunct zones, one in far south-western Northern Territory and adjacent parts of Western Australia and far north-western South Australia, the other in far northern New South Wales (Fig. 7). Grows in red sand on dunes associated with *Triodia pungens*.

Notes: Leaflets are variable in shape and often have raised pinnate, forward-angled secondary venation. Pairs of leaflets are inserted quite close together towards the upper midline of the rachis rather than at the sides (Fig. 8a). In a specimen from near Uluru (Ayers Rock), in the Northern Territory (*Lazarides & Palmer 293* CANB), a small proportion of leaves have alternate lateral leaflets. A specimen from Cumborah in New South Wales (*Cunningham & Mulham 4162* NSW) differs from other specimens in being virtually glabrous and having longer leaflets. This form warrants further investigation.

Aenictophyton onomolum is transferred here from

Ptychosema based on a suite of similarities it shares with other species of *Aenictophyton*, including inflorescence architecture, shape of the hypanthium, shape of calyx lobes, striping of the hypanthium and calyx, and relative lengths of the petals. A flower is shown in figure 8b and can be compared to a flower of *A. reconditum* shown in figure 8d. The imparipinnate leaves of *A. anomalum* are very similar to those of *Ptychosema pusillum*; however its floral morphology is markedly different to that of the latter. An imparipinnate leaf may be interpreted as a primitive feature for a clade comprising *Ptychosema* and *Aenictophyton*, in which case the reduction in leaflet number in *A. reconditum* may then be interpreted as a derived feature. Leaf, inflorescence and flower morphology of *A. anomalum* are shown in figure 8a–c.

Although designating MEL 26461 as the holotype of *P. anomalum*, Lee (1973) effectively lectotypified this specimen from two possible sheets. In her paper, Lee did not discuss her reasons for selecting one sheet over the other. Her choice is considered suitable.

4b. *Aenictophyton reconditum* A.T.Lee, *Contr. New South Wales Natl. Herb.* 4(7): 422 (1973)

Type: Northern Territory. Willis Rockhole, c. 30 miles [48 km] E of Sandy Blight Junction, *W.H.Butler 110*, v.1967; holotype: PERTH01003585; isotype: PERTH01003593.

Plants to c. 80 cm high, glabrous or with fine spreading hairs to c. 0.2 mm long on most surfaces, variably glabrescent. *Stipules* narrow-triangular, mostly 1–2 mm long, 0.2–0.7 mm wide, to c. 5 mm long on stems and sometimes dentate, coriaceous, pale brown. *Leaves* tending to become lost with age, to c. 40 mm long on stems but much smaller on shorter branches; petiole 1–4 mm long; leaflet narrow oblong-elliptic to linear, to c. 35 mm long, to 4 mm wide, flat or concave, with apex sometimes recurved. *Primary inflorescences* several-flowered; bract 1–3 mm long; pedicels mostly 1–2(–3) mm long, glabrous or hairy, becoming strongly recurved, or rarely (in putatively aberrant plants) 3–15 mm long and straight; bracteoles 1–1.5(–2) mm long, 0.2–0.5 mm wide, inserted 0.5–1 mm below receptacle, or rarely up to 6 mm below when the pedicel is long. *Hypanthium* 1.5–2 mm long; calyx 3–5 mm long, with a scattered indumentum of short spreading hairs or glabrous, or with very few appressed hairs; lobes as long as or slightly longer than tube; standard 5–10 mm long, 5–9 mm wide; wings 5–9 mm long, 1.5–2 mm wide; keel 5–8 mm long, 2–2.5 mm wide; anthers 0.3–0.4 mm long; style 1.5–2.5 mm long. *Pods* with stipe 4–8 mm long, equal to or more often clearly exceeding calyx; body narrow-oblong or oblong-elliptic, 12–25 mm long, 3.5–5 mm wide, 1–4-seeded. *Seeds* broad-ellipsoid, c. 2.5 mm long; aril c. 0.3 mm long, to 0.4 mm high, with a curved lobe.

Notes: Flowers of *A. reconditum* and *A. anomalum*

Figure 7. Distributions of a. *Aenictophyton anomalum*, b. *A. reconditum* subsp. *reconditum*, and c. *A. reconditum* subsp. *mocrophyllum*.

Key to subspecies of *A. reconditum*

1 Plants pubescent with short spreading hairs, variably glabrescent; pedicels hairy at flowering; leaves < 2 mm wide ..... subsp. ***reconditum***

1: Plants ±glabrous (sparse appressed hairs on new growth only); pedicels glabrous at flowering; largest stem leaves > 2 mm wide ..... subsp. ***macrophyllum***

can be compared in figures 8b & 8d. Pod and seed morphology are shown in figures 8e–f. Aril morphology is similar to that of species of *Muelleranthus* (with the exception of the exarillate *M. stipularis*; see figures 4k & 4m). At maturity, funicles in pods of *A. reconditum* are directed strongly retrorsely, more so than has been seen in other species of the study group.

Two subspecies are recognised.

Aenictophyton reconditum subsp. *reconditum*

Plants pubescent with short spreading hairs, variably glabrescent. *Leaves* to c. 25 mm long, to c. 2 mm wide. *Pedicels* hairy at flowering. *Calyx* 3–4.5 mm long, with a scattered indumentum of short spreading hairs; lobes c. as long as tube, upper lobes with filiform points to c. 0.5 mm long.

***Selected specimens of c. 20 examined*: WESTERN AUSTRALIA**: Airstrip Bore, NW of Lake Mackay, *M.G.Corrick 11102* (CANB, MEL, PERTH); Dragon Tree Soak, Great Sandy Desert, *A.S.George 14787*, 10.viii.1977 (CANB, PERTH); Parry Range Walk, 16 km SSW of Cane River Station, 80 km E of Onslow, *D.J.Edinger 1661*, 27.v.1999 (PERTH); 11 km E of Kiwirr kurra, Gibson Desert, *P.K.Latz 15772*, 5.xi.1998 (CANB, DNA). **NORTHERN TERRITORY:** c. 48 km W of Mongrel Downs HS, *R.Maconochie 984* (AD, DNA, NSW); Tanami track c. 472 km NW of Alice Springs, *P.A.Fryxell, L.A.Craven & J.McD.Stewart 4500*, 25.v.1985 (CANB, MEL274528); Lake Mackay, on island in SE of lake, *P.K.Latz 12898*, 11.x.1992 (CANB, DNA, MEL278780); c. 43 km SW of Inningarra Range, *J.Maconochie 936*, 2.viii.1970 (BRI, NSW).

Flowering period: Flowers winter and spring.

Distribution and habitat: Occurs in northern Western Australia and far western Northern Territory (Fig. 7). Grows in red sand dunes in open shrublands and grasslands in deserts.

Notes: Flowers of *A. reconditum* and *A. anomalum* can be compared in figures 8b & 8d. Pod and seed morphology are shown in figures 8e–f. Aril morphology is similar to that of species of *Muelleranthus* (with the exception of the exarillate *M. stipularis*; see figures 4k & 4m). At maturity, funicles in pods of *A. reconditum* are directed strongly retrorsely, more so than has been seen in other species of the arid genera.

Three collections of *A. reconditum* subsp. *reconditum* from widely separated locations, near Onslow, (*Edinger 1661* PERTH), Gibson Deset, (*Latz 15772* CANB, DNA), and the Inningarra Range, (*Maconochie 936* NSW), comprise multiple pieces which show a marked dichotomy in pedicel morphology. Pedicels are long and erect in some pieces but short and recurved, as is typical of the species, in the remaining pieces. Although the plants with long, erect pedicels possibly represent a distinct taxon, it is also quite possible that the plants are merely aberrant forms that occasionally develop in this subspecies of *A. reconditum*. Until further information is available it is thought prudent to not taxonomically recognise this form.

Mature seeds have not been recorded for this atypical form. In the collection from near Onslow, the piece with the atypical pedicels also has numerous semi-developed pods. These may represent pods of unfertilised flowers, and they may have reached their final size. In *Maconochie 936* the atypical piece bears a few pods that are more developed and are of a size typical of the species; however, they do not appear to have any developing seeds inside.

Aenictophyton reconditum subsp. *macrophyllum* **I.Thomps.,** *subsp. nov.*

A subspecie typica plantis glabratis, foliis majoribus differt.

Type: 20.1 km SE of Burranbar Pool on Savory Creek, Little Sandy Desert, Western Australia, *S. van Leeuwen 3267*, 19.viii.1997; holotype: PERTH07015100; isotype: DNA186222, CANB713747, *n.v.*

Plants glabrous except for appressed hairs on newest growth. *Leaves* to c. 40 mm long, to 4 mm wide, with largest leaves 2–4 mm wide. *Pedicels* glabrous at flowering. *Calyx* 4–5 mm long, glabrous or with a few

Figure 8. *Aenictophyton*. a–c. *A. anomalum*: a. leaf (*M.Lazarides & J.Palmer 293* CANB), b. flower, c. raceme (b & c. *P.K.Latz 15636* DNA-NT). d–f. *A. reconditum* subsp. *reconditum*, d. flower (*A.S.George 14787* PERTH), e. pod (*P.K.Latz 15772* CANB), f. seed (*P.A.Fryxell 4500* CANB). g. *A. reconditum* subsp. *macrophyllum*, leaf and nodal region (*G.Davis 120* CANB). Scale bars: a = 10 mm, b, d = 2 mm, c, e, g = 5 mm, f = 0.5 mm.

lines of short, appressed hairs in distal half; lobes slightly longer than tube; upper lobes with filiform points c. 0.5–1 mm long. *Seeds* not seen.

Remaining specimen examined: **WESTERN AUSTRALIA**: SW of Nullagine and NE of Noreena Downs Stn, *G.Davis 120*, 10.viii.1979 (CANB, PERTH).

Flowering period: Flowers recorded July and August.

Distribution and habitat: Occurs in central Western Australia east and north-east of Newman (Fig. 7). Grows in skeletal red soils in lateritic hills in low open woodland.

Etymology: The subspecific epithet refers to the relatively large leaves (From Greek: *macros*, large and *phyllon*, leaf).

Notes: *Aenictophyton reconditum* subsp. *macrophyllum* is known from only two collections but is considered sufficiently distinct to warrant recognition at the level of subspecies. It has larger leaves than the type subspecies and plants are glabrous apart from scattered, appressed caducous hairs on new growth. The flowers are a little larger and calyx-lobes have longer filiform tips. A portion of a stem leaf of *A. reconditum* subsp. *macrophyllum* is shown in figure 8g.

Acknowledgments

I am grateful to the Royal Botanic Gardens, Melbourne, particularly Alison Vaughan and the collections staff for their assistance with mapping and loan processing, and to the directors of AD, BRI, CANB, MEL, NSW and PERTH for making their collections available for study. Greg Keighery provided valuable input regarding *Ptychosema pusillum*. This study was funded by a grant from the Australian Biological Resources Study (ABRS Grant no. 207-01), which is a program within the Department of Sustainability, Environment, Water, Population and Communities.

References

Bentham, G. (1839). 'A sketch of the vegetation of the Swan River Colony'. In J.Lindley (ed.), *Edwards's Botanical Register*, **Appendix to Vols 1–23**. James Ridgway: London.

Crisp, M.D. (1981). '*Muelleranthus*.' In J.P.Jessop (ed.), *Flora of Central Australia*, *Australian Systematic Botany Society*, p. 152. Reed: Sydney.

Crisp, M.D. and Weston, P.H. (1987). 'Cladistic and legume systematics, with an analysis of the Bossiaeeae, Brongniartieae and Mirbelieae'. In C.H.Stirton (ed.), *Advances in Legume Systematics*, **Vol. 3**, pp. 65–130. Royal Botanic Gardens, Kew: London.

Crisp, M.D. and Cook, L.G. (2003). 'Phylogeny and embryo sac evolution in the endemic Australasian papilionoid tribes Mirbelieae and Bossiaeeae'. In B.Klitgaard and A.Bruneau (eds), *Advances in Legume Systematics*, **Vol. 10**, pp. 253–268. Royal Botanic Gardens, Kew: London.

Hutchinson, J. (1964). *The Genera of Flowering Plants*, **Vol. 1**, p. 361. Oxford University Press: London.

Lee, A.T. (1973). A new genus of Papilionaceae and related Australian genera. *Contributions from the New South Wales National Herbarium* **4**, 412–430.

Lullfitz, B., Konnur, A., Alderton, J., Jolliffe, D., and Squire, M. (2008). *Threatened and poorly known flora of the Yilgarn Region*. Department of Environment and Conservation: Western Australia.

Thompson, I.R. (2011a). A revision of *Goodia* (Bossiaeeae: Fabaceae). *Muelleria* **29**, 141–153.

Thompson, I.R. (2011b). A revision of *Platylobium* (Bossiaeeae: Fabaceae). *Muelleria* **29**, 173–189.

A morphological comparison between *Digitaria coenicola* and *D. divaricatissima* (Poaceae: Paniceae)

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Abstract

Morphometric analysis supports the inclusion of *Digitaria coenicola* (F. Muell) Hughes within *D. divaricatissima* (R. Br.) Hughes. *Digitaria macractinia* (Benth.) Hughes, previously regarded as synonymous with *D .divaricatissima* is resurrected as a variety *D. divaricatissima* var. *macractinia.*

Keywords: taxonomy, tufted grasses, species differentation

Muelleria 29(2): 190-200 (2011)

Introduction

Digitaria Haller, with around 218 species (Vega *et al.*2009) is the third most speciose genera within tribe Paniceae (after *Panicum* L. c. 470 species, *Paspalum* L. c. 330 species; Clayton & Renvoize 1986). *Digitaria coenicola* (F. Muell.) Hughes and *D. divaricatissima* (R.Br.) Hughes belong to the entirely Australian section *Pennatae*, which includes those species with inflorescences having whorled branches at the lowest node and spikelets absent from the lower 1/3 of those branches. The other species of the section are *D. ammophila* (Benth.) Hughes, *D. basaltica* B.K.Simon, *D. benthamiana* Henrard, *D. hystrichoides* Vickery, *D. nematostachya* (F.M.Bailey) Henrard, *D. papposa* (R.Br.) P.Beauv., and *D. porrecta* S.T.Blake.

As currently delimited, *Digitaria coenicola* and *D. divaricatissima* are perennial, tufted grasses (Walsh & Entwisle, 1994). They occur in semi-arid, temperate and subtropical areas, mainly in central and eastern Australia. In Victoria, these species occur in grasslands and grassy woodlands of the Wimmera and Riverina regions (Conn 1992), with general localities including Dimboola, Charlton, Mitiamo, Dookie and Springhurst. They are distinguished from other *Digitaria* species in that they have relatively long (≥3.5 mm) spikelets and inflorescences of unbranched, radially arranged racemes devoid of spikelets toward their bases (Sharp & Simon 2002).

Whether these two species are clearly distinct has been a source of some conjecture. Walsh (1994) noted that the two species are separable by the width and hairiness of the space between the midrib of the lower (sterile) lemma and the adjacent longitudinal nerve. However it was further noted that some specimens have lemmas with both hairy and glabrous internerve spaces. Webster (1984) noted that the separation of the two species based on these characters is 'rather artificial in that these characters are highly correlated'. He later noted (Webster 1987) that *D. coenicola* 'is closely related to *D. divaricatissma*' but persisted in using the width and hairiness of the internerve space to separate the species, as have subsequent treatments (e.g. Harden 1993, Sharp and Simon

2002; Simon *et al. ined.*). Other characters traditionally used to separate the species include the length of the upper glume compared to lower lemma, the presence of hairs in the primary branch axil, the number of nerves on the lower lemma and the degree of hairiness of the vegetative structures (Hughes 1923; Henrard 1950).

Victorian populations have been referred to as both *Digitaria divaricatissima* and *D. coenicola*. However they are all currently recognised as *D. divaricatissima* which is regarded as a vulnerable species in the state (Walsh & Stajsic 2007). Should both taxa be accepted as occurring in Victoria, the conservation status of either is likely to be more critical, so an accurate assessment of the taxonomy is desirable before conservation plans for the populations can be developed.

This study seeks to evaluate the characters used to differentiate the two species and arrive at a practical, applicable taxonomy for the taxa.

Materials and Methods

Measurements were obtained from 39 *D. divaricatissma* and 37 *D. coenicola* specimens from the National Herbarium of Victoria (MEL), and specimens collected fresh in the course of this study. Measured specimens included types of *D. coenicola*, *Panicum divaricatissima* R.Br. var. *glaberrima* Benth, and *Panicum macractinium* Benth., the latter two taxa currently regarded as synonyms of *D. divaricatissima* (Simon *et al. ined.*). As far as possible, specimens used were those that had recent, authoritative determinations by recognised experts (e.g. R.D. Webster or B.K. Simon). Specimens were selected to cover the geographic range of the taxa (Fig. 1).

Figure 1. Distribution of the herbarium specimens analysed; *Digitaria coenicola* (circles) and *D. divaricatissima's* (triangles) ranges.

D. coenicola and *D. divaricatissima* are not geographically disjunct although *D. coenicola* is generally regarded as having a more westerly distribution than *D. divaricatissima*, such that only the former is recognised in WA, NT and SA and only the latter in Vic.

A list of the most definitive quantitative and qualitative traits used in published treatments (e.g. Wheeler *et al.* 1982; Harden 1993; Webster 1987; Sharp & Simon 2002; Simon *et al. ined.*) to separate the species was compiled (appendix 1). Initially, 29 characters were measured. Once these characters were analysed in PATN software, 11 were excluded because they did not contribute to the separation of the data between the species. Measurements were taken using either a Leica M80 dissecting microscope or Olympus SZX16 microscope with measurement accuracy to 0.01 mm. Detailed images of spikelet features were captured electronically via an Olympus DP71 camera.

Analysis

All quantitative data were entered into a data matrix in PATN v3 (Belbin 2004). PATN software employs a Gower's (1971) association co-efficient to unite most similar elements into groups. Utilising these groupings, a dendrogram was produced to determine the groups' statistical support. An ordination illustration was compiled to represent the relationship between the two species. From this, Kruskal Wallis values were obtained for every character to identify those that were most useful in discriminating groups.

All qualitative traits were entered into Microsoft Excel and a series of graphs comparing these characters was compiled.

Results

Quantitative characters

PATN software separated the specimens into three groups in the dendrogram (Fig 2). One group comprised *D. divaricatissima* specimens only and the other two groups comprised of both *D. coenicola* and *D. divaricatissima* specimens. PATN based these three groupings on characters predominantly (in order of weight) primary branch length (Kruskal Wallis value 38.57), maximum leaf

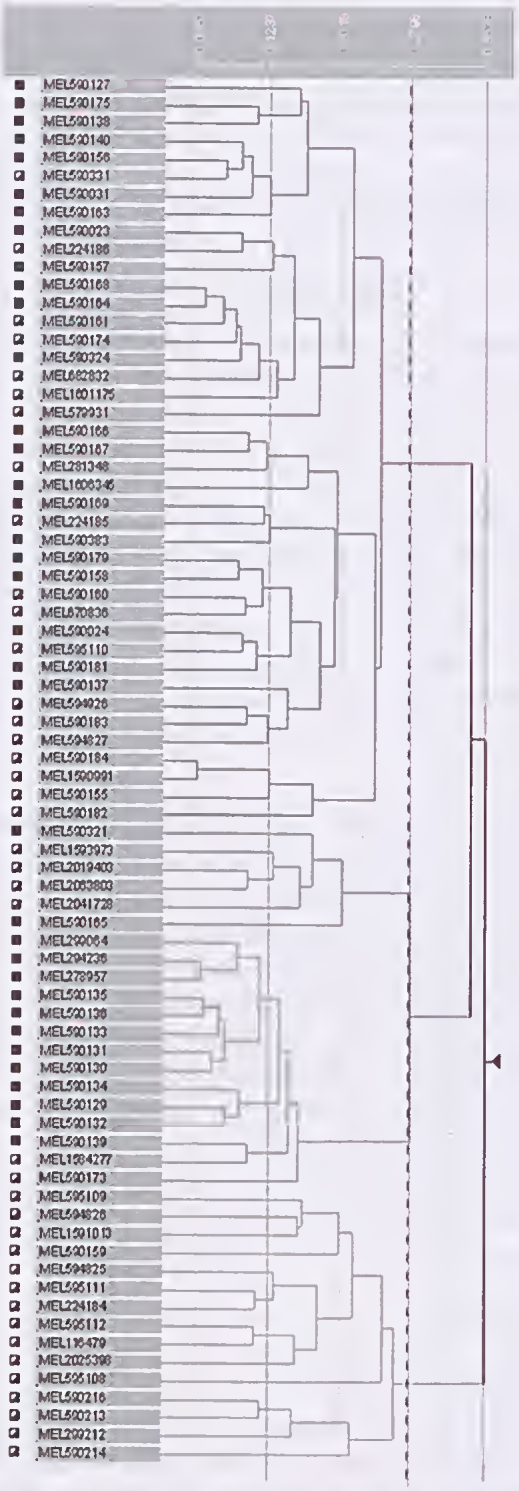

Figure 2. Dendrogram of Gower's association coefficients displaying *Digitaria divaricatissima* (diagonally divided squares) and *D. coenicola* (solid squares) specimens, based on 13 quantitative traits; groupings indicated at a similarity coefficient of 0.2798.

width (Kruskal Wallis value 37.42), anther length (Kruskal Wallis value 33.83), ratio of first to second lemmatal internerve width (Kruskal Wallis value 25.88) and first internerve width (Kruskal Wallis value 23.87).

As shown in Fig 3, the PATN ordination (stress value 0.1632) does not display any clear groupings or separations of *D. coenicola* and *D. divaricatissima*. Whilst specimens determined as *D. coenicola* are generally located near the upper right portion of the ordination and the *D. divaricatissima* specimens are located near the lower left portion, there is too much overlap between the species to recognise distinct entities on the basis of this analysis. PATN has predominantly based this ordination on, (in order of weight), primary branch length, maximum leaf width, anther length, the ratio of the first to second internerve width and the first internerve width.

Qualitative characters

The two traits most commonly utilised to separate *D. divaricatissima* and *D. coenicola* are the width of the first versus second lemmatal internerve space and the hairiness of the first internerve space on the lower lemma. The *D. divaricatissima* spikelet shown in Fig. 4 is a 'typical' specimen, i.e. one that exhibits *D. divaricatissima* morphology in accordance with current circumscription of the species, exhibiting a glabrous first internerve space and a wider first compared to second internerve space on the lower lemma.

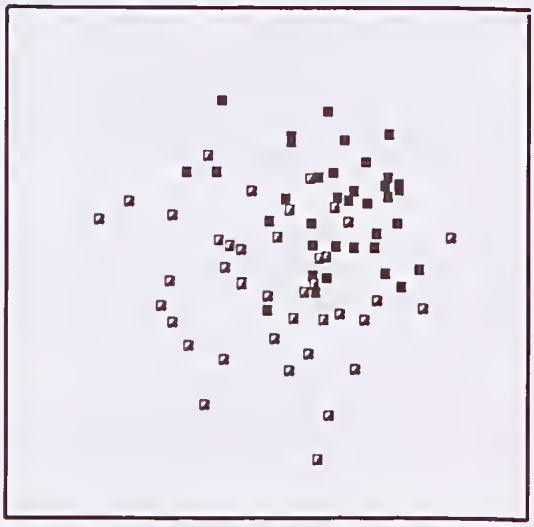

Figure 3. PATN ordination of *Digitaria divaricatissima* (diagonally divided squares) and *D. coenicola* (solid squares) specimens, based on 13 quantitative traits.

Figure 4. Typical spikelet of *Digitaria divaricatissima* (MEL 224184).

D. coenicola spikelets shown in Fig. 5a and 5b exhibit 'typical' *D. coenicola* morphology. These spikelets demonstrate equal lemmatal internerve spacing and a hairy first internerve space. Whilst some spikelets exhibited this morphology, many displayed contrasting morphological traits. The *D. coenicola* spikelet shown in Fig. 5c is a good example of the variation that can exist within the same spikelet. One half of the spikelet in Fig. 5c has sub-equal internerve spacing and the other possesses a distinctly wider first internerve space relative to the second. Similar to the variable internerve spacing shown in Fig. 5c, the hairiness of the first internerve can vary substantially, even within the same specimen. Many specimens were found to have hairy or glabrous first internerve spacing within the same inflorescence. Sometimes, individual spikelets had both hairy and glabrous first internerve spaces (Fig. 6).

To determine if other factors could enable species separation, simple scatter-plots were created using only the traits utilised in recent taxonomic treatments (e.g. width of lemmatal internerve space versus hairs in internerve space, the ratio of the first internerve to second internerve space, and whether either of these are correlated with leaf hairiness).

The width of the first lemmatal internerve varied greatly, from 0.08 mm to almost 0.19 mm. When *D. coenicola* and *D. divaricatissima* specimens first lemmatal internerve space width and hairiness are graphed, the specimens are not segregated nor does the graph display any clear trends (Fig.7a). When the ratio of first to second lemmatal internerve widths of *D. coenicola* and *D. divaricatissima* are graphed there is no clear distinction between species. When the hairiness of the internerve space is overlayed onto the same scatter plot there is no obvious difference between *D. coenicola* and *D. divaricatissima* specimens (Fig. 7b).

Digitaria divaricatissima and *D. coenicola* specimens also overlap with regard to leaf blade hairiness. Both have specimens with glabrous, hairy and mixed glabrous and hairy leaves. When leaf blade hairiness is combined with the ratio of the first to second internerve space width, the analysis still does not separate the species (Fig. 8).

Discussion

The current treatments of *D. coenicola* and *D. divaricatissima* present a number of inconsistencies that do not allow ready recognition of the two taxa. In this study we measured 13 different quantitative traits on 76 specimens. PATN did not separate the specimens into two groups, corresponding with *D. coenicola* and *D. divaricatissima*, but rather, into three groupings that did not accord well with the specimen's determinations or other patterns of morphology or distribution. Rather the results suggest these species are probably better recognised as a single, although variable species. To date, there have been no accounts formally suggesting the two species should be merged, although some (Walsh & Entwisle 1994; Webster 1987) have suggested that that the characters currently separating the species are highly inconsistent.

Species separation has traditionally been supported by qualitative traits. The four characteristics frequently used are (a) leaf blade hairiness, (b) first versus second lemmatal internerve width (a derived qualitative trait), (c) hairiness of the first lemmatal internerve and (d)

Figure 5. Typical spikelets of *Digitaria coenicola* a). (MEL 590127) and b). (MEL 590175). Non-typical spikelet of *Digitaria coenicola* c). (MEL 590158).

number of nerves on the lower lemma (often hard to determine accurately).

Hairy leaf blades have been typically associated with *D. coenicola*, whereas *D. divaricatissima* has glabrous leaf blades (Simon *et al. ined.*). Our observations indicate that this division is not always accurate. Many *D. divaricatissima* and *D. coenicola* specimens showed both glabrous and hairy leaf blades, whereas some possessed solely glabrous or hairy leaf blades. With such overlap between the degree of hairiness, this character does not support the retention of two species. We suspect that leaf blade hairiness is, at least in some cases, ontogenetic and perhaps also an ecotypic trait. Younger plants observed in the field (up to one year old) had long, dense hairs on leaf blades, whereas older plants (2 years plus) in the same population had either glabrous leaf blades or ones with much shorter, sparser hairs.

Digitaria coenicola is generally regarded as having a hairy first lemmatal internerve space while *D. divaricatissima* has glabrous first internerve spaces (e.g. Simon *et al. ined.*). Our results were not so distinct. *D. coenicola* specimens had both hairy and glabrous internerve spaces, specimens of *Digitaria divaricatissima* with 'authoritative' determinations exhibiting similar variation. There were also individual spikelets on some specimens that displayed both hairy and glabrous first internerve spaces.

It has been commonly accepted that *D. coenicola* has equal lemmatal internerve spacing whereas *D. divaricatissima* has a larger first versus second internerve

Figure 6. Non-typical spikelets of *Digitaria divaricatissima* (MEL.590174, both spikelets from the same specimen).

space (e.g. Sharp & Simon 2002). When we measured all internerve spaces (to within 0.01 mm accuracy) we obtained different results to previous studies. For both species, all but two specimens had a larger first versus second internerve space. The majority of specimens had first lemmatal internerve spaces up to 1.75 times the width of the second internerve. This contrasts previous findings that record *D. coenicola* as having subequal inter-nerve spacing.

Specimens exhibit significant geographical variation. Key characters which are geographically variable are lemmatal internerve spacing and the hairiness of the lower lemma. Whilst our results from the southern part of the species' range are highly variable, specimens from the Northern Territory (hitherto all identified as *D. coenicola*) are generally consistent with respect to the internerve spacing and hairiness of the lower lemma.

While scoring *D. divaricatissima* for the analysis, a number of specimens were observed with characteristics that distinguished them from all other specimens. Instead of the fine, spreading, sometimes tangled hairs on the intramarginal keels of the lemmas,

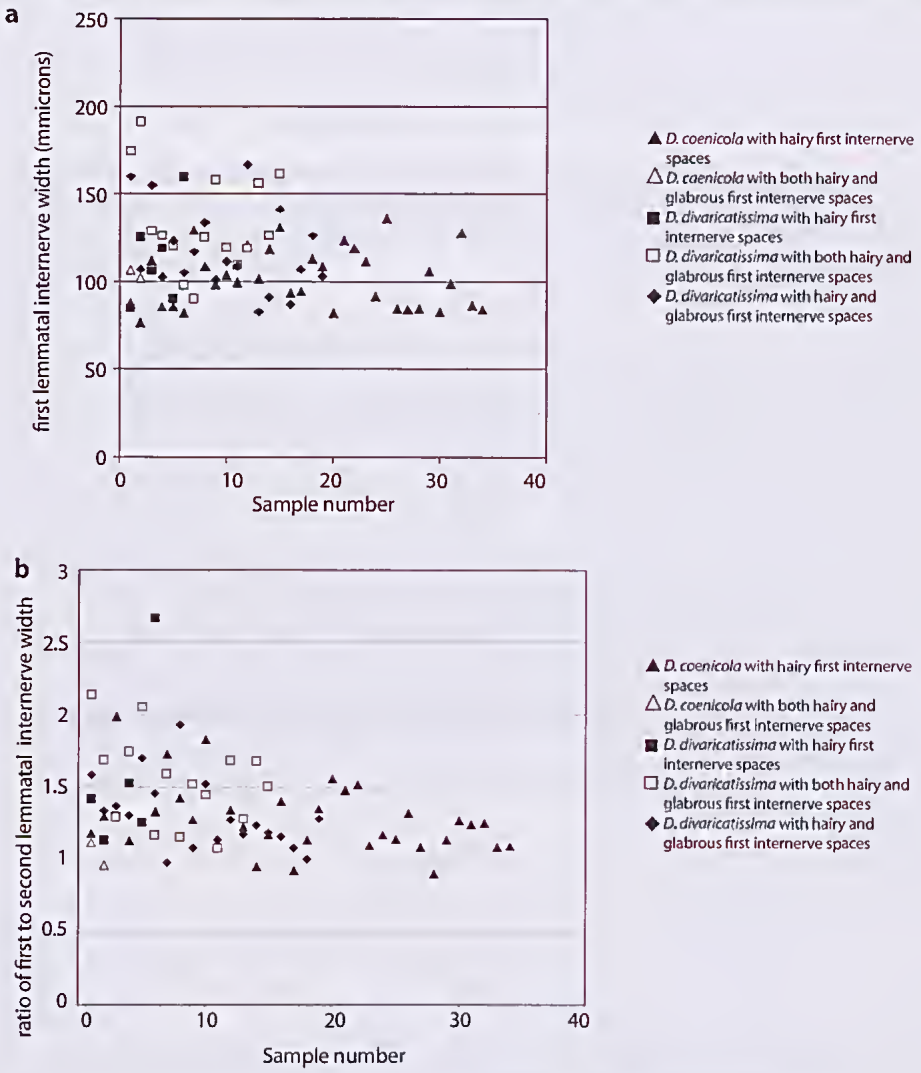

Figure 7. a). The width of the first lemmatal internerve space of *Digitaria coenicola* compared to *D. divaricatissima* specimens; b). The ratio of first to second lemmatal internerve space width of *Digitaria coenicola* compared to *D. divaricatissima* specimens. Specimens with the first internerve space hairy, glabrous or both are indicated. The X-axis does not indicate dimension, but the number (randomly) assigned to each specimen in this plot.

they possessed distinctive coarse, hollow, tubercle-based bristles (Fig. 9). This group of specimens also had less hairy leaves and primary branch axils than other specimens. All had glabrous internerves on the lower lemma. These match the type of *Digitaria macractinia* (Benth.) Hughes, a taxon synonymised with *D. divaricatissima* in contemporary treatments (e.g. Webster 1987; Sharp & Simon 2002; Simon *et al. ined*). Henrard (1950) and Webster (1984) discussed the significance of these bristles ('setaceous hairs' *sensu* Webster 19B4) as taxonomic characters and indicated that they were produced in a number of not necessarily closely related species. Henrard (1950) used this character to recognise distinct taxa at specific or intraspecific rank, whereas Webster generally acknowledged it as occasional variation within species (although generally present in *D. ctenantha* (F. Muell.) Hughes) and not warranting further taxonomic recognition. Our observations found this highly distinctive character to be consistent within collections (unlike those characters previously employed to distinguish *D. coenicola* and *D. divaricatissima*) and we advocate taxonomic recognition of such plants. To date, we have only found material of this entity amongst specimens from Queensland.

The results of the numerical analysis, our examination of herbarium material and field populations suggest that *D. coenicola* should be regarded as synonymous with *D. divaricatissima* as outlined below. We propose that plants with hollow, tubercle-based bristles on the lower lemmas, previously referable to *D. macractinia* but subsequently included in *D. divaricatissima* be recognised again. We provide a new varietal combination for these, *Digitaria divaricatissima* var. *macractinia*. (Benth.) H.L.Stewart & N.G.Walsh.

Taxonomy

Digitaria divaricatissima (R.Br.) Hughes var. *divaricatissima Bull. Misc. Inform. Kew* 1923: 314 (1923)

Panicum divaricatissimum R.Br., *Prodr.* 192 (1810); *Leptoloma divaricatissima* (R.Br.) Chase, *Proc. Biol. Soc. Wash.* 29: 192 (1906). T: Port Jackson, *R.Brown Iter Australiense 6118*; holo: BM; iso: BRI, E, K (photo BRI).

Panicum divaricatissimum var. *glaberrimum* Benth. *in part*, *Fl. Austral.* 7: 46B (1B78). T: Rockhampton and neighbourhood, *A. Thozet s.n.*; lecto (here chosen): MEL!; isolecto: BRI. Remaining syntype: Peak Downs, *Burkitt s.n.*; syn: K(photo BRI). Rejected type: Gracemere, *P.A.O'Shanesy* 1441 (MEL590177!, BRI).

Panicum divaricatissimum var. *normale* Benth., *Fl. Austral.* 7: 46B (1878). T: Keppel Bay, Qld, *R.Brown*; syn: BM; Port Jackson, N.S.W., *R.Brown*; syn: BM.

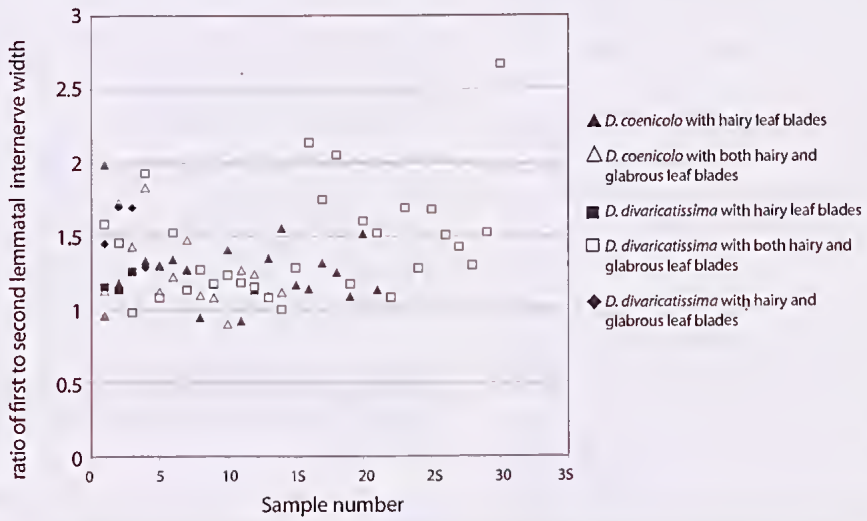

Figure 8. The ratio of first to second lemmatal internerve space width for *Digitaria coenicola* compared to *D. divaricatissima* specimens. Specimens with leaf blades hairy, glabrous or both are indicated. The X-axis does not indicate dimension, but the number (randomly) assigned to each specimen in this plot.

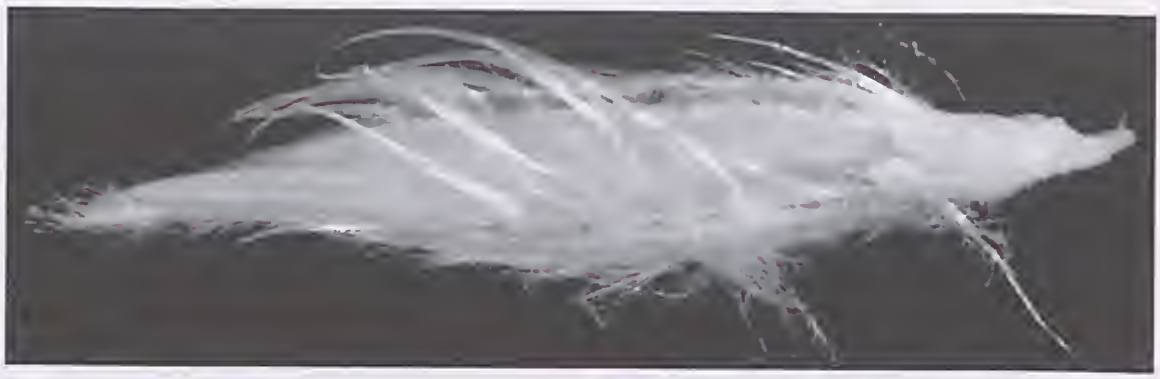

Figure 9. Typical spikelet of *Digitaria divaricatissima* var. *macractinia* (590214) with the upper glume removed.

D. divaricatissima (R.Br.) Hughes var. *dasyantha* Henrard, *Monogr. Digitaria* 199 (1950). T: Austr: haud rara, *Hugel s.n.*; syn: ?W; in Australia tropica, *Bauer s.n.*; syn: ?W.

Panicum tenuissimum var. *polychaeton* Domin, *Bibl. Bot.* 85: 296 (1915). T: Süd-Queensland: Tambourine Mountains, in den Regenwäldern, *K.Domin s.n., Mar.* 1910; holo: PR..

Panicum coenicola F.Muell., *Trans. & Proc. Roy. Soc. Victoria* 1: 45 (1855) as *coenicolum*; *Leptoloma coenicola* (F.Muell.) Chase, *Proc. Biol. Soc. Wash.* 19: 192 (1906). T: towards Morunde, and near Cudnaka, S.A., *F.Mueller s.n.*; holo; MEL!; iso: BRI, K.

D. macractinia (Benth.) Hughes subsp. *leichhardtiana* Henrard, *Monogr. Digitaria* 830 (1950). T: in railway enclosure, Blair Athol, Leichhardt District, Qld, 16 Mar. 1935, *S.T.Blake B091 p.p.*; holo: L , iso: BRI, K.

D. macractinia (Benth.) Hughes var. *nudiflora* Henrard, *Monogr. Digitaria* 831 (1950). T: near Rockhampton on mid slopes of Mt Berserker, Qld, 6 Mar. 1937, *S.T.Blake 12721 p.p.*; holo: L; iso: BRI, K.

Shortly rhizomatous, more or less caespitose, perennial. *Culms* erect to decumbent, 20–70 cm tall, 2–7 noded. *Leaves*: sheaths hairy or glabrous; ligule 0.8-3.7 mm long; blades flat, 2–22 cm long, 2–7 mm wide, hairy or glabrous, scabrous. Primary branch axil with fine to dense hairs. *Racemes* 4–10, usually devoid of spikelets at base, long and rigid, simple, 5–36 cm long. Central axis 2–9 cm long. Pedicels 0.3–8.3 mm long, apices cupuliform. *Spikelets* 8–30 on a typical lowermost primary branch, hairy, paired, lanceolate or elliptical, 3.4–5.1 mm long, 0.9-1.4 mm wide; lower glume 0.4-1.6 mm long, ovate oblong, elliptical or triangular, 0-1 nerved, membranous, smooth, glabrous, acute to obtuse or rounded to cleft rounded; upper glume 1.7–5 mm long, as long as spikelet, triangular or lanceolate, 3-7 nerved, with ciliate or non-ciliate margins and sub-margins, hairy, villous, rounded, acuminate, or acute. *Lower floret*; lemma 3–5 mm long, hairy, with indumentum shorter than the spikelet, without hair tufts, with a hairy or glabrous first internerve space, with the first internerve space wider than the second or equal to the second, with margins or submargins glabrous, 5-7 nerved; palea vestigial, or absent. *Upper floret* shorter or subequal to the lower floret; lemma 2.9–5 mm long, brown, cartilaginous to indurate, muricate, lanceolate, acute to acuminate, mucronate, lanceolate, apiculate. *Umbrella Grass or Finger Panic Grass.*

Habitat and Distribution: Arid, semi-arid and drier temperate areas of all mainland States, but apparently rare in Western Australia.

Note on type: Bentham included O'Shanesy 1441 as a type of *P. divaricatissimum* var *glaberrimum*. We include this specimen in *P. divaricatissima* var *macractinia*.

Digitaria divaricatissima var. *macractinia* (Benth.) Heather L.Stewart & N.G.Walsh, comb. nov.

Panicum macractinium Benth., *Fl. Austral.* 7: 468 (1878); *Leptoloma macractinia* (Benth.) Chase, *Proc. Roy. Soc. Wash.* 19: 192 (1906); *Panicum divaricatissimum* R.Br. var. *macractinium* (Benth.) Domin, *Biblioth. Bot.* 85: 293

(1915); *Digitaria macractinia* (Benth.) Hughes, *Bull. Misc. Inform. Kew* 1923: 314 (1923). T: Herbert's Ck, *Bowman s.n.*; lecto: K; isolecto: BRI, MEL!, *fide* D.K.Hughes, *loc. cit.*

D. macractinia subsp. *muelleriana* Henrard, *Monogr. Digitaria* 865 (1950) *nom. inval*, (this is the type variety as stated by Henrard *loc cit*).

Differing significantly from the typical variety only in the presence of a line of stiff, hollow bristles arising from a tuberculate ridge on the intramarginal keels of the lower lemma (Fig. 9). Furthermore, all specimens examined to date have glabrous internerves on the lower lemma, and spikelet length is in the upper range of measurements for the species (4.0–5.1 mm long).

Representative specimens: **QUEENSLAND:** Warwick, *H.Beckler s.n., s.d.* (MEL); Rockhampton, *P.A.O'Shanesy, s.n., s.d.* (MEL); New Holland, *Banks & Solander*, 1770 (MEL595109); Gracemere, 4.i.1874, *P.A.O'Shanesy 1441* (MEL); Between Lanefield and Rosewood, 12.iv.1930, *C.E.Hubbard 2134* (K, MEL); Between Laidley and Forest Hill, 28.ix.1930, *C.E.Hubbard 5350* (K, MEL594826); Wington Island, NE of Mackay, *A.R.Bean 16690 & I.G.Champion* 26.vi.2000 (BRI, MEL305885).

Habitat and Distribution: Known to us only from Queensland, from scattered localities between Mackay and Ipswich areas, up to about 100 km inland, but undoubtedly commoner than our records suggest as we have not had the opportunity to examine material from other Australian herbaria. Collectors' notes indicate that it grows on 'heavy black soil' and 'sand or coral rubble' in open country and in 'littoral rainforest and strand communities'.

Notes: Henrard (1950, pp. 864, 865) indicates that his *D. macractinia* subsp. *muelleriana*, is the 'typical form'. The other 2 infraspecific entities (subsp. *leichhardtiana* and var. *nudiflora*) lack bristles on the lemmas and are regarded as the typical variety of *D. divaricatissima*.

Further collections of this possibly rare taxon are required for an accurate assessment of its conservation status. We encourage field workers to note consistency of the characters outlined above, so that its rank may more confidently be reviewed if required.

Acknowledgments

We are indebted to Eris O'Brien, Trust for Nature, who generously gave of his time and knowledge to assist in the location and collection of *Digitaria* in north-central Victoria, to Niels Klazenga for his expertise in using PATN software, to Alison Vaughan for creating the distribution map of MEL specimens, to David Cantrill for assistance with use of the photomicroscope and associated software , and to Teresa Lebel for assistance with preparing maps and images for publication.

The Peate Studentship, awarded to HS, funded this study. The generosity of Natalie and Roger Peate, botanical enthusiasts, in providing this studentship is gratefully acknowledged.

References

Belbin, L. (2004). *PATN. Pattern analysis package* (version 3.02), CSIRO: Canberra.

Clayton, W. and Renvoize, S. (1986). *Genera Graminum: grasses of the world*. Royal Botanic Gardens Kew **13**, 1–389.

Conn, B.J. (1992). 'Vegetation and natural regions of Victoria' in D.B. Foreman & N.G. Walsh (eds), *Flora of Victoria* vol. 1. pp 79–158. Inkata Press: Melbourne.

Gower, J.C. (1971). A general coefficient of similarity and some of its properties. *Biometrics* **27**, 857–871.

Harden, G.J. (1993). *Flora of New South Wales*, vol. 4. NSW University Press: Sydney, Australia.

Henrard, J.T. (1950). *Monograph of the genus* Digitaria, Universitaire Pers. Leiden: Netherlands.

Hughes, D. (1923). The Genus *Panicum* of the *Flora Australiensis*. *Bulletin of Miscellaneous Information* **9**, 305–14.

Sharp, D. and Simon, B. (2002). *AusGrass: Grasses of Australia*. CSIRO Publishing: Collingwood, Victoria, Australia.

Simon, B.K., Weiller, C.M. and Webster, R.D. *Ined.*, *Flora of Australia* Volume 44B, Poaceae 3. CSIRO Publishing/ Australian Biological Resources Study (ABRS): Canberra, Australia.

Vega, A., Rua, G., Fabbri, L. and Rugolo de Agrasar, Z. (2009). A morphology-based cladistic analysis of *Digitaria* (Poaceae, Panicoideae, Paniceae), *Systematic Botany*. **34**, 312–323.

Walsh, N.G. (1994). '*Digitaria* (Poaceae)' in Walsh, N.G. and Entwisle, T.J. (eds), *Flora of Victoria* vol. 1, pp. 606–610. Inkata Press: Melbourne, Australia.

Walsh, N.G. and Stajsic, V. (2007). *A census of the vascular plants in Victoria*, edn 8. Royal Botanic Gardens Melbourne: Victoria.

Webster, R.D. (1984). A revision of the genus *Digitaria* Haller (Paniceae: Poaceae) in Australia. *Brunonia* **6**, 131–216.

Webster, R.D. (1987) *The Australian Paniceae (Poaceae)*. J. Cramer: Berlin.

Wheeler, D.J., Jacobs, S.W. and Norton, B.E. (1982). *Grasses of New South Wales*. University of New England: Armidale, Australia.

Appendix 1

Table of all characters measured. The 13 characters in bold were used in the final quantitative analysis, the 5 italicised characters were utilised in qualitative analysis. The remaining 11 were excluded when PATN analysis demonstrated they did not contribute at all to the species separation or amalgamation.

Characters	**Measurements/states**
Blade	
Maximum width	mm
Hairiness	glabrous, sparse or dense
Cataphyll length	mm
Ligule	
Maximum length	mm
Sheath	
Hairiness	glabrous, sparse or dense
Primary branches	
Maximum length	mm
Hairiness of axil	glabrous, very fine, fine or hairy
Scabrosity	glabrous or scabrous
Inflorescence	
Maximum length	mm
Pedicel	
Maximum length	mm
Spikelet	
Maximum length	mm
Minimum length	mm
Maximum width	mm
Shape	lanceolate or elliptical
Hairiness	glabrous, appressed, semi-appressed or wooly
Lower/outer/first glume	
Length	mm
Shape	ovate, lanceolate, triangular, truncate top
Number of nerves	0 or 1
Upper/inner/second glume	
Maximum length	mm
Minimum length	mm
Number of nerves	
Hairiness of margins	appressed, semi-appressed, woolly
Lemma	
Maximum length	mm
Minimum length	mm
Number of nerves	
Hoiriness of internerve spoce odjacent to mid-nerve	glabrous, hairy
Width of internerve space adjacent to mid-nerve	mm
First vs second internerve width	equal, bigger or smaller
Anther length	mm

Corrigendum

Muelleria 29(1)

K. Rule and W.M. Molyneux (2011). Two new mallee Eucalypts (Myrtaceae) from Gippsland, Victoria. *Muelleria* 29(1):16-26.

Declaration of holotypes and isotypes clarified.

P18. *Eucalyptus ornans* Molyneux & Rule sp. nov.

Type: VICTORIA. Avon Channels, 37° 48' 20" S 146° 52' 34" E, 14.iv.2005, *K. Rule 3805* (holotype MEL 2328846; isotypes AD, CANB, NSW).

P22. *Eucalyptus forresterae* Molyneux & Rule sp. nov.

Type: VICTORIA. 6.2 km along Brumby Point Track from Diggers Hole Spur Road, 37°03'30" S 148°04'33" E, 15.xi.2008, *W. Molyneux & S. Forrester s.n.*, (holotype MEL 2828603; isotypes AD, CANB, HO, NSW).

P.B. Adams (2011). New combinations and two new central Queensland taxa in the *Dendrobium tetragonum* (Orchidaceae:Epidendroideae) complex. *Muelleria* 29(1): 69-80.

Authorship of certain taxa clarified.

P.77. *D. tetragonum* A. Cunn. subsp. *tetragonum* var. *meleucophilum* (M.A. Clem. & D.L. Jones) Dockrill

P.78. *D. tetragonum* A. Cunn. subsp. *giganteum* (Leaney) P.B. Adams *var cacatua* (M.A. Clem. & D.L. Jones) Dockrill.

MUELLERIA INSTRUCTIONS FOR CONTRIBUTORS

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Birdwood Avenue South Yarra VIC 3141
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heading level 3: followed by text on the same line.

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References. Only publications cited in the text should appear in the Reference list. List chronologically.
Journal names in full. Floras in a series to be cited in book format.

Allan, H.H. (1961). *Floro of New Zeolond*. R.E. Owen, Government Printer: Wellington.

Ahti, T. and Kashiwadani, H. (1984). 'The lichen genera *Clodlo*, *Clodino* and *Clodonio* in southern Chile'. In H. Inoue (ed.), *Studies on the cryptogoms of southern Chile*, pp. 125–149. Kenseisha Ltd: Tokyo.

Brummitt, R.K. and Powell, C.E. (1992). *Authors of plont nomes*. Royal Botanic Gardens: Kew.

Jarman, S.J. (1975). *Experimentol toxonomy on the fomily Epocridoceoe*. PhD thesis, The University of Tasmania, Hobart: Tasmania.

Pickett, J.W., Smith, N., Bishop, P.M., Hill, R.S., Macphall, M.K. and Holmes, W.B.K. (1990). A stratigraphic evaluation of Ettingshausen's New England Tertiary plant localities. *Austrolion Journol of Eorth Sciences* **37**, 293–303.

Swofford, D.L. (2000). *PAUP. Phylogenetic onolysis using porsimony (version 3.1.1.)* Illinois Natural History Survey: Champaign, USA.

Walsh, N.G. (1994). 'Poaceae'. In N.G. Walsh and T.J. Entwisle (eds), *Floro of Victorio*, **Vol. 2**, pp. 356-627. Inkata Press: Melbourne.

Muelleria

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www.rbg.vic.gov.au

ISSN 0077-1813

Contents

Volume 29(2), 2011

Contributed papers

Page

The lichen genera *Japewia* and *Japewiella* in Tasmania 99
– G. Kantvilas

Sex discrimination of Buloke (*Allocasuarina luehmannii*) for selective revegetation 104
– M. Conomikes, M. Wright and J. Delpratt

Resolution of the *Thelymitra aristata* (Orchidaceae) complex of south-eastern Australia 110
– J. Jeanes

The functional significance for the orchid *Caladenia tentaculata* of genetic and geographic variation in the mycorrhizal fungus *Sebacina vermifera* s. lat. 130
– M. Wright, R. Cross, R.D. Cousens, T.W. May and C.B. McLean

A revision of *Goodia* (Fabaceae: Bossiaeeae) 141
– I.R. Thompson

A revision of *Platylobium* (Fabaceae: Bossiaeeae) 154
– I.R. Thompson

A revision of *Muelleranthus*, *Ptychosema* and *Aenictophyton* (Fabaceae: Bossiaeeae) 173
– I.R. Thompson

A morphological comparison between *Digitaria coenicola* and *D. divaricatissima* (Poaceae: Paniceae) 190
– H. Stewart and N. Walsh

Corrigendum

Muelleria 29(1): (2011) 201